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LAUNCH MONITOR SUBSYSTEM

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

The Mercury requirement for the Launch Monitor Subsystem is derived from the need for precision in orbiting the manned capsule and landing it in predetermined recovery areas. To insure the safety of the astronaut, the capsule must be accurately placed in the desired orbit. If a tolerable orbit is not achieved, control personnel must be immediately aware of this fact so that re-entry can be initiated. Prompt and safe recovery of the astronaut also requires that the position of the capsule be known throughout the mission so that the point of re-entry and landing can be accurately timed.

Throughout the launch and insertion period, at intervals during the three orbital passes and during re-entry, the Mercury flight is observed from ground installations. Radar and telemetry provide position, velocity, and discrete event data concerning the launch vehicle and capsule. Mission decisions and control operations are based on this raw data. Whether to abort or continue the mission, the safe duration of the mission, and the optimum re-entry location must be decided. The raw data, however, is not in a form permitting rapid and precise decision.

The Launch Monitor Subsystem has been designed to accept the raw data and to operate upon it in near real time in order to provide derived quantities suitable for display and decision-making. The subsystem receives raw data, processed radar data, telemetry event data, human decisions, and range condition information. This information is operated upon in near real time by a digital computer complex in accordance with programs appropriate to the mission phase. Derived quantities, such as trajectory parameters, timing, telemetry data, and recommendations concerning orbital capability and recovery area are then presented to flight controller personnel for decision.

Although the Launch Monitor Subsystem operates as a single system, its components are located at three sites: Cape Canaveral, Goddard Space Flight Center at Beltsville, Md., and Bermuda. Facilities at Cape Canaveral provide for buffering of launch data and its transmission to Goddard and for reception and distribution of processed data to the Mercury Control Center (MCC) displays. At Goddard, a central computing installation receives and processes data and then transmits it to the Mercury Control Center or range stations as appropriate. The Bermuda portion of the subsystem is a secondary computing site which serves as a backup to the Cape Canaveral—Goddard Complex during the launch and insertion phase.

The Launch Monitor Subsystem as a whole performs the following general functions:

a. Accepts radar, guidance, telemetry, and decision data from the launch site and range stations.

b. Transfers the data to computers.

c. Processes the raw data.

d. Provides output display quantities and recommendations.

e. Provides output acquisition data.

f. Transmits data to control centers.

g. Distributes data to displays.

The allocation of these functions to the subsystem sites is indicated in figure 1-1.

1.2 SCOPE

This manual explains the operational use of the Launch Monitor Subsystem. Physical details of specific equipments are not covered since they are available in referenced documents. Equipment is described in terms of use and external connections and indicators.

The functional description of the Launch Monitor Subsystem, as a system, during each mission phase is supplemented by a discussion of information transfer, traffic delays, and malfunctions. Finally, the events and processes occurring in the Launch Monitor Subsystem during a mission are related to the chronological sequence of events for the total Mercury mission.

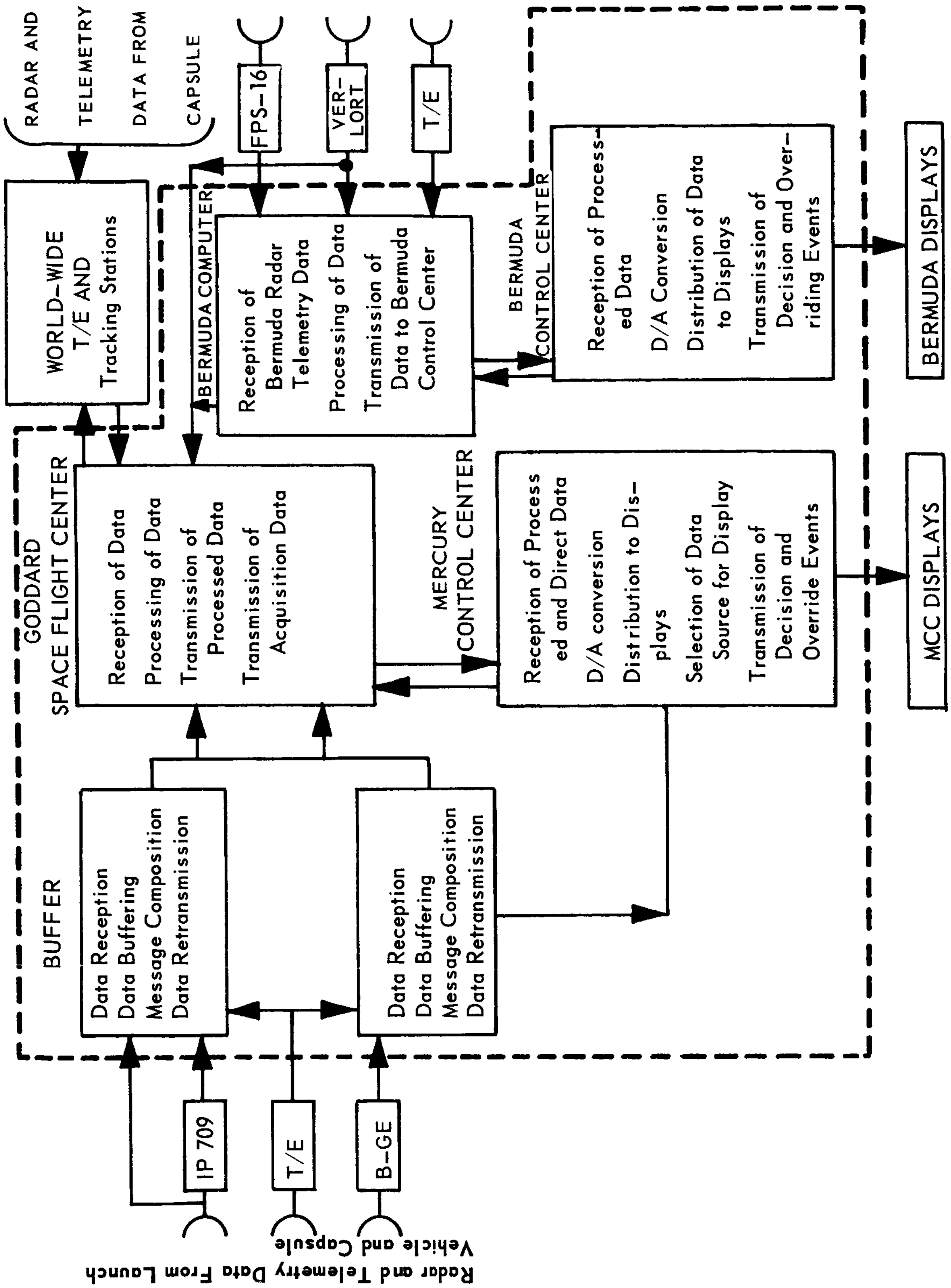


FIGURE 1-1. MERCURY LAUNCH MONITOR SUBSYSTEM, SYSTEM DIAGRAM

CHAPTER 2

FUNCTION OF LAUNCH MONITOR SUBSYSTEM

The basic function of the Launch Monitor Subsystem — to receive, transmit, compute, and distribute data — remains the same throughout the Mercury mission. However, as the mission progresses from phase to phase, there are important changes in the raw data sources and the quantities derived for display. This chapter describes the information transfer and data transformation for each phase.

2.1 PRELAUNCH

The use of the Launch Monitor Subsystem in a Mercury mission is the end point of an extensive series of equipment and system testing efforts. Unit tests, interaction tests, and mission simulation tests will demonstrate that the individual equipments and the system as a whole function in accordance with design requirements. After this demonstration, normal preventive maintenance and system exercise procedures will, insofar as possible, keep the system at an operational level.

These routine procedures, however, are not adequate for providing operational personnel with the necessary high level of confidence that the system will function as required at the time of a scheduled mission. To determine the readiness of the system for an actual mission, a checkout of the system will be made in the hours preceding the launch. This checkout procedure when completed will indicate to operational personnel whether the subsystem is functioning properly and will continue (within some confidence limits) to do so during the mission.

The activities that take place during the prelaunch period of the Mercury mission generally fall into the following categories:

a. Unit checkout
b. Communications checks
c. Interaction checks
d. System roll call
e. Status reports
f. Mission simulation
g. System confidence check procedures
h. Final preparation for launch

Before the subsystem can be expected to respond as a functioning entity, each element must be brought up to its operating capacity and these elements joined through a series of carefully developed procedures. The exact programs and procedures to be used during the prelaunch period are now under development. These procedures must take into account the complexity of the subsystem and its interaction with launch vehicle, capsule, and ground system prelaunch activities. Timing is a critical factor. Specific procedures are being evolved from experience gained through the Computation and Data Flow Integrated Subsystem Test (CADFISS) program and early Mercury missions.

It is necessary to co-ordinate and schedule those operations and times during which the Launch Monitor Subsystem will need support from areas external to the subsystem. Conversely, there are parts of the total Mercury system that will require support from the Launch Monitor Subsystem in carrying out their checkout operations. All potentially conflicting operations must be treated so that compatibility of operations is maintained. Chapter 5 includes chronological sequence of events of pre-launch activities. This information will be issued at a later date. Where required, detailed statements of procedures will also be provided.

2.2 LAUNCH AND INSERTION

From liftoff through insertion, the Launch Monitor Subsystem is actively engaged in receiving track and discrete event information, processing this information to make it suitable for display, and finally presenting the information thus derived to the appropriate consoles and plot boards used for both information and decision-making purposes. During the launch and insertion phase, there are a rapid succession of events and a number of decisions to be made in a relatively short period of time. Because of this, the information must be processed and displayed as near real time as possible. Real-time display is approached by using components such as high-speed transmission lines and a high-speed digital computing machine (IBM 7090) with real-time input capabilities for the data-processing function.

During the launch phase, the Goddard computing center depends upon two sources of data: the Burroughs-GE Complex and the IP 709 Complex. The IP 709 Complex is capable of sending two types of data messages: data reduced by the IP 709 computer and raw radar returns. The transfer of information from each source to Goddard is treated separately except where it becomes necessary to consider more than one at a time.

2.2.1 Burroughs—GE Data

The Burroughs—GE Complex is a system specially designed to compute and transmit guidance and discrete commands to the launch vehicle which will be used to put the capsule in orbit. These computations are based on trajectory and discrete information received from associated radar and telemetry devices. Also based on these radar and telemetry returns is the information relayed to the Goddard computing center.

The data messages sent to Goddard, first pass through a high-speed buffer and retransmitter located in the Burroughs building at Cape Canaveral. This equipment converts the parallel information it receives from the Burroughs computer into serial format. These data, together with serial telemetry information received directly from the telemetry event buffer located in the Mercury Control Center, are assembled into message units. The complete messages are then sent to Goddard for further processing. Transmission is accomplished over a duplexed set of high-speed transmission lines at a rate of 1000 bits per second. Each complete message frame leaving the high-speed buffer consisting of 384 bits is composed of two 192-bit subframes. A subframe includes an identification word indicating which half of a message is involved. This is necessary since the subframes contain different information and must be processed differently when they enter the computer at Goddard. The nominal rate for repeating the complete 384-bit message frame is once every 500 milliseconds. This rate is tempered by having a tolerance of ±100 milliseconds which is governed by the amount of internal branching done by the Burroughs computer program.

Position and velocity vectors describing the trajectory of the missile constitute the bulk of the information contained in the message frames. The contents and internal structure of these message frames are shown in figure 2-1. It should be noted here that the positioning of certain quantities within the structure of the message frame is classified information. Quantities represented by the letters G, H, J, K, L, M, and N shown in figure 2-1 are such quantities. For further information concerning these quantities, reference should be made to other documents. The telemetry portion of the message indicates the phase or subphase of the mission, and whether certain discrete events have occurred. The telemetry portion of the message also contains the capsule elapsed time reading and the retrofire mechanism setting. The discrete word in the message format gives an indication of the type and quality of data being transmitted, the 2-inch liftoff signal, booster engine cutoff (BECO) and sustainer engine cutoff (SECO), and a GO, NO-GO recommendation as determined by the Burroughs computer.

In the event that the quantities G, H, J, K, L, M, and N are not available for transmission, the entire message frame is sent at a rate of once every 600 milliseconds. In place of the missing data, 0's interspersed with 1's are transmitted. If the telemetry portion of the message is not available, the same procedure of interspersing 1's among 0's is followed. In both cases, these 1's are not randomly distributed but placed in particular positions. These patterns of

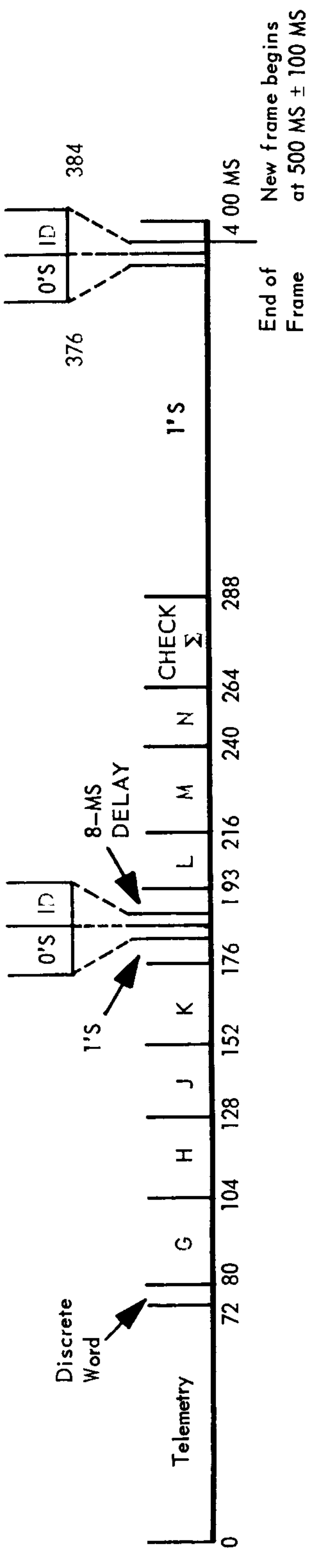


FIGURE 2-1. BURROUGHS-GE DATA, POSITIONING AND TIMING WITHIN MESSAGE

0's with 1's in key positions inform the 7090 computer at Goddard that the information normally contained in these portions of the format is not available. This arrangement precludes the possibility that the 7090 programs might try to recognize and operate on these portions as if they contained valid data.

2.2.2 IP 709 Data

The IP 709 Complex normally operates as part of the Cape Canaveral facility. Its function in this capacity is to provide track and rate information and altitude of apogee, and to give a continuous prediction of impact if thrust were immediately terminated. During Project Mercury launch operations, it continues to serve range personnel in this manner. In addition, and without any impairment of this normal service, this complex supplies data to the computing center at Goddard. The arrangement for buffering and high-speed transmission to Goddard is similar to the setup in the Burroughs Complex. However, to provide compatibility with the output of the 709 computer, the buffer accepts 36 parallel bits of information instead of 24 as in the Burroughs case.

The IP 709 computer receives its data from one of several radars. These are located at Canaveral, Grand Bahama, and San Salvador Islands. The 709 computer supplies smoothed trajectory data to the buffer and retransmitter, which relays this data to Goddard. This high-speed buffer also receives telemetry information directly from the telemetry event buffer in the Mercury Control Center and includes this information in each message sent to Goddard. All information leaving the IP 709 retransmitter is sent to the Goddard computing center at a rate of 1000 bits per second, and each complete message frame is repeated once every 400 milliseconds. The contents and internal structure of these messages going to Goddard are shown in figure 2-2.

As in the case of the information supplied by the Burroughs-GE Complex, the bulk of the messages from the IP 709 retransmitter is composed of position and velocity vectors describing the flight path of the launch vehicle. Again it should be noted that the positioning of certain quantities within the message format is classified information. Quantities represented by the letters A, B, C, D, E, F, and N shown in figure 2-2 are such quantities. For further information concerning these quantities, reference should be made to other documents. The telemetry portion of the message frame is identical with the telemetry portion of the messages sent by the retransmitter in the Burroughs building; that is, it indicates the phase or subphase of the mission, the status of the mission, and whether certain discrete events have occurred.

A complete message frame from the IP 709 retransmitter is composed of 384 bits of information. This complete frame is divided into two 192-bit subframes. Each subframe includes an identification word which indicates to the Goddard computer which half of a message is involved.

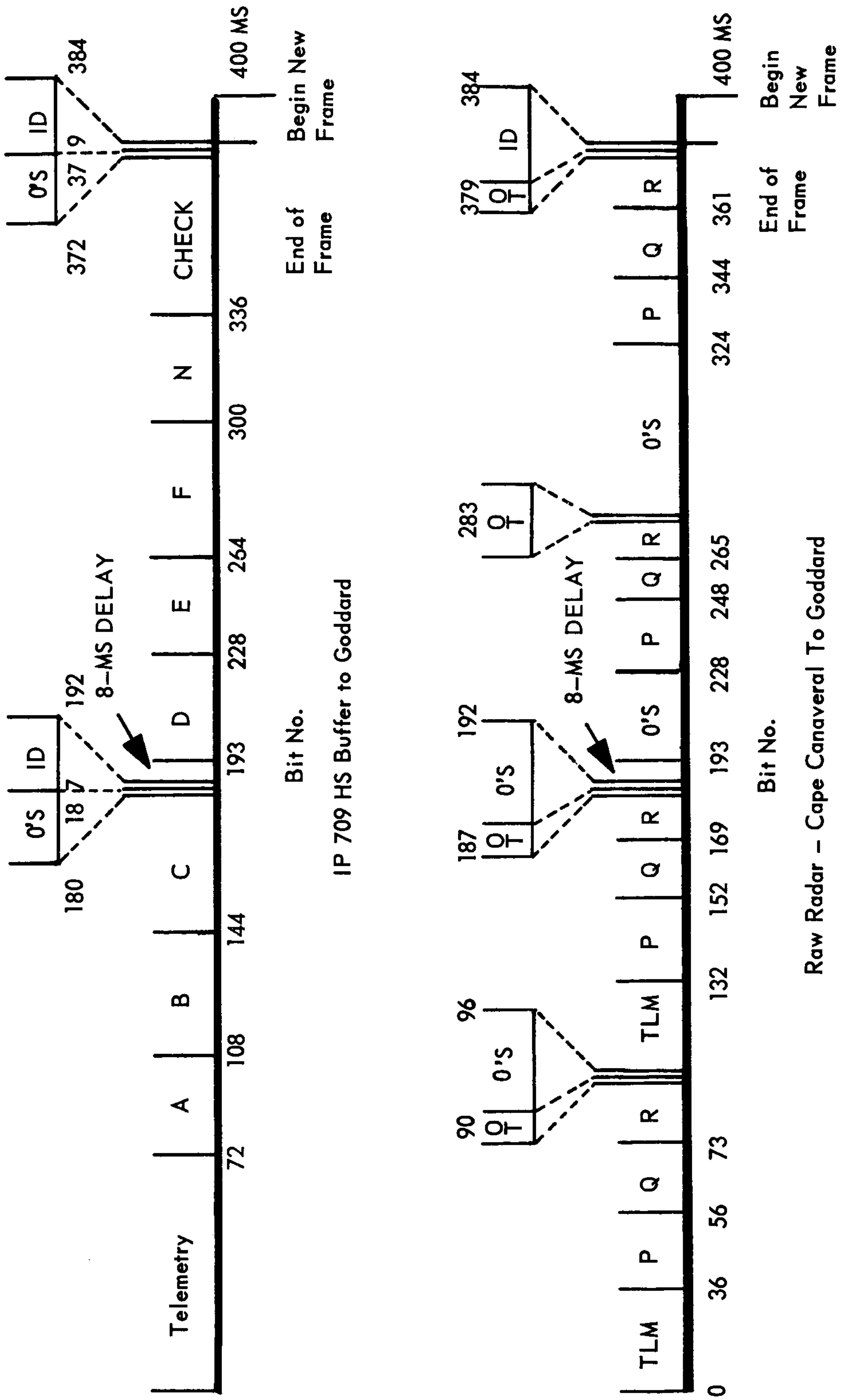


FIGURE 2-2. IP 709 AND RAW RADAR DATA, POSITIONING AND TIMING WITHIN MESSAGE

2.2.3 Raw Radar Data

If a malfunction or loss of power occurs in the IP709 computing equipment, raw radar returns may be manually selected for transmission to Goddard. During the short period of time between the loss of valid information from the IP709 computer and the switch to raw radar, the erroneous or missing information is replaced by 0's interspersed with 1's in particular positions to indicate faulty data. Once the switch to raw radar is accomplished, the data content of the messages is composed primarily of range, azimuth, and evaluation fixes. The location of these quantities within the message structure is classified information. The raw radar message is 384 bits in length and it too is divided into two 192-bit subframes, each containing an identification word. In addition to indicating the subframe of a message, this identification word also tells which particular radar set is supplying the data. The normal telemetry event information is included in the raw radar message format and contains its usual information.

The messages coming from both the Burroughs Complex and the IP 709 computer contain checksums within their format. This makes it possible for the 7090 at Goddard to verify that no error was introduced in the transmission system.

2.2.4 Goddard Space Flight Center

All high-speed information arriving at Goddard enters two IBM 7090 computers operating in parallel. These computers are entered by means of a Data Communications Channel supplied for each computer. This input device is covered in paragraph 4.1.2.1, Chapter 4. During a normal launch operation, the computers at Goddard each accept both Burroughs supplied data and IP 709 supplied data. Certain relationships are derived from each source of data and displayed to determine which source is prime. This data selection function is covered in detail in paragraph 4.3.1, Chapter 4. The Goddard computers are advised by the Data Selection Supervisor as to which source of data is more valid or prime, and all quantities and relationships describing flight performance are derived from this source of data by the Goddard computers. (The Burroughs computer calculations several quantities and sends them directly to the Mercury Control Center for display.)

The Goddard computers serve two functions during the launch and insertion portion of the mission. First they derive and present in a form suitable for display and decision making a number of factors representing time, position, and velocity. Secondly, they compute and give a go or no-go recommendation to help the Flight Dynamics Officer decide either to abort or to insert the capsule into orbit. The information derived by the Goddard computers is transferred to Data Communications Channels and ultimately transmitted over high-speed lines to the Mercury Control Center at Cape Canaveral at a rate of 1000 bits per second.

The message frames leaving Goddard are referred to as odd or even frames of information. A complete message consists of an odd and an even frame, each 408 bits in length. Messages are received at a rate of two subframes per second during launch. Figure 2-3, a layout of message subdivision within the frames, shows which bits are used to drive each particular plot board or console involved. The symbols and terms used in this graph are defined in Appendix A.

2.2.5 Mercury Control Center

The Mercury Control Center, during the launch and insertion operations, monitors and considers the factors influencing the performance of all airborne and ground-based personnel and equipment contributing to the mission. To assist control center personnel in this task, the messages arriving from Goddard are analyzed for quality and are disassembled and distributed to the proper display devices. In some cases, this digital information must be converted into analog quantities to be compatible with the display concerned. The equipment and operations required to perform the tasks of analyzing, distributing, and converting this information are described in Chapter 4.

Table 2-1 is a summary of all the quantities received from the Goddard computing center. It should be noted that the format of messages received from Goddard is constant for all phases of the mission, the only differences being the repetition rate and the contents. The variation in contents can be clarified by the fact that certain quantities are useful in one phase and not in another. In any phase of the mission where a quantity is not needed, the bit positions in the format allocated to this quantity are all 0's.

In general, the data driving displays at the Mercury Control Center during the launch phase may come from the 7090 computers at Goddard or direct from the Burroughs-GE guidance system. In some cases, these are alternate sources subject to selection by the Data Selection Supervisor. Plot Boards I and II and the GO, NO-GO indication on the Flight Dynamics Officer's Console are in this category. However, some of the data is available only from the Burroughs-GE Complex at Cape Canaveral. These quantities are as follows:

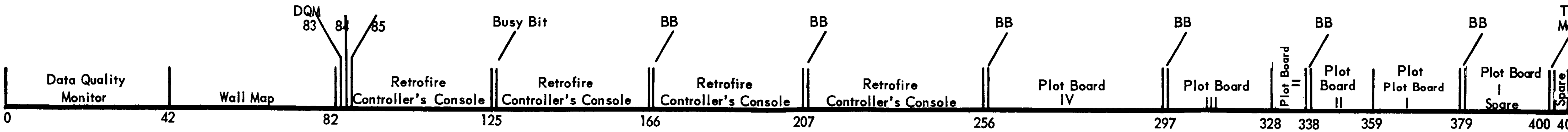
a. All information displayed on Plot Board III.

b. V/V_R - V/V_R nom and $\gamma - \gamma$ nom for the Burroughs-GE direct channels of the Data Quality Monitor strip chart recorder.

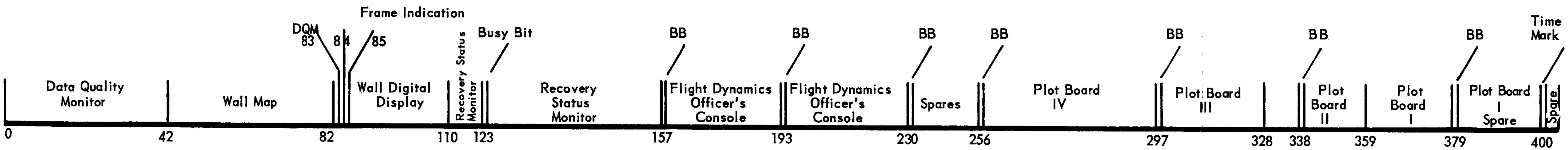
c. δ 1, 2, 3, n Burroughs-GE flags which appear on the Data Selection Console.

d. BECO and SECO indicators on the Telemetry Monitor Console.

Figure 2-4 shows the format of data from the Burroughs-GE to the Mercury Control Center.



Milliseconds and Bit No. Even Frame



Milliseconds and Bit No. Odd Frame

Plot Board I ˜$V_{/VR}$ γ, V, r-$\bar{R}$

Plot Board II ˜d, h, Y-Y_{nom}, t_e, a-$\bar{R}$

Plot Board III ˜t_e, λ_p, ϵ

Plot Board IV ˜λ_{IP}, ϕIP, $\lambda_{30\ sec}$, $\phi_{30\ sec}$, $\lambda_{max\ del}$, $\phi_{max\ del}$,

Flight Dynamics Officer's Console ˜Go-No-Go, r-$\bar{R}$, γ, ha, inclination angle orbit capability, $V_{/VR}$, V

Retrofire Controller's Console ˜GMTRC for abort, ECTRC for abort, GMTRS now, GMTRC end pres. orbit, ECTRC end pres orbit, EGT since Retrofire, GMTRC end 3 orbits, ECTRC end 3 orbits, ICTRC, ΔT, Retard setting, Recovery Area.

Recovery Status Monitor Console ˜GMTLC, λ landing, ϕ landing

Wall Digital Display ˜GTRS, orbit in progress, Time to landing

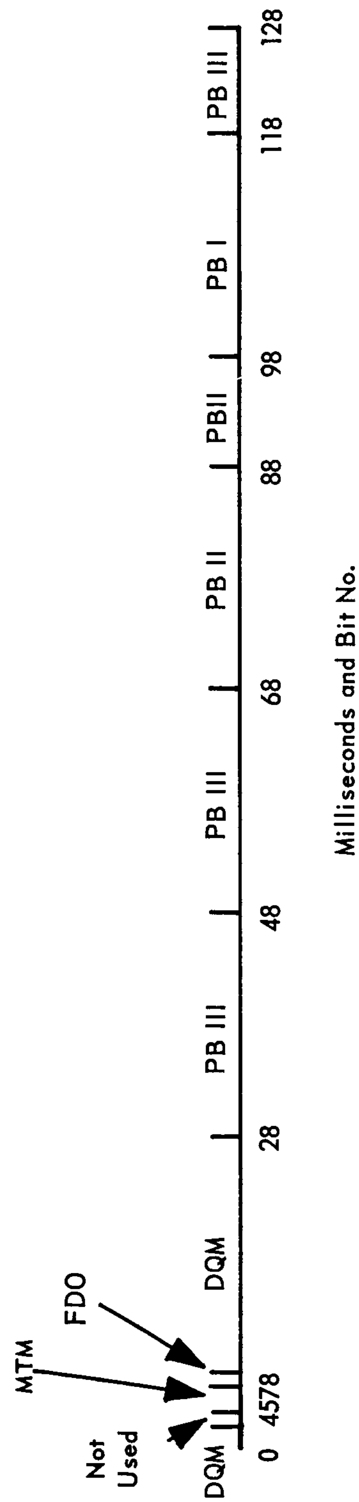
Wall Map Display ˜λ_{PP}, ϕ_{PP}, λ_{IP}, ϕ_{IP}, $\lambda_{30\ sec}$, $\phi_{30\ sec}$

Data Quality Monitor ˜$V_{/VR}$ - $V_{/VR\ norm}$, time, γ - γ_{norm}, data source

FIGURE 2-3. GODDARD TO MERCURY CONTROL CENTER, MESSAGE LAYOUT

TABLE 2-1. DATA FROM GODDARD – BY PHASE

Display Area	Item	Phase Displayed			
		Launch	Abort	Orbit	Re-entry
Flight Dynamics Officer's Console	GO-NO-GO	x	x		
	$r - \bar{R}$	x	x	x	x
	i	x		x	
	h_a	x	x		
	γ	x	x		x
	Orbit cap.	x			
	V/V_R	x			
	V		x	x	x
Retrofire Controller's Console	GMTRC for abort		x	x	
	ECTRC for abort		x	x	
	GMTRS now			x	
	GMTRC end pres. orbit			x	
	ECTRC end pres. orbit			x	
	EGT since retrofire				x
	GMTRC end 3 orbits			x	
	ECTRC end 3 orbits			x	
	ICTRC		x	x	
	ΔT	x			
	Recovery area	x	x	x	x
Recovery Status Monitor Console	GMTLC		x	x	x
	λ landing		x	x	x
	ϕ landing		x	x	x
Wall Displays	GTRS		x	x	
	Time till landing				x
	Orbit No.			x	x
Wall Map	λ PP	x	x	x	x
	ϕ PP	x	x	x	x
	λ IP		x		x
	ϕ IP		x		x
	λ 30 sec.			x	
	ϕ 30 sec.			x	



DQM – Data Quality Monitor
MTM – Missile Telemetry Monitor
FDO – Flight Dynamics Officer
PB – Plot Board

FIGURE 2–4. BURROUGHS–GE TO MERCURY CONTROL CENTER, DATA FORMAT

Another source of information is the Capsule Communicator's Console. When the capsule communicator has determined that the received telemetry signals are in error, he may override these signals at the console. These override bits are transmitted to Goddard by way of the Burroughs and 709 buffers.

2.2.6 Bermuda Complex

As far as transfer of data is concerned, the Bermuda Complex is nearly independent during launch and insertion operations. The Bermuda site exists to back up and/or aid in making certain decisions normally made in the Mercury Control Center. To operate in this manner, the Bermuda Complex includes both Verlort and FPS-16 radars, an IBM 709 computer with peripheral equipment, and several display devices. Bermuda also has facilities for receiving the normal telemetry event information from the capsule and for talking with the astronaut.

Early in the launch phase, Bermuda receives acquisition data from Goddard by means of teletype. These acquisition messages are sent every 30 seconds, beginning 2-1/2 minutes after liftoff, and the final one is sent 4 minutes after liftoff. Once the Bermuda radars begin tracking the capsule, the IBM 709 computer receives range, azimuth, and elevation at a rate of 10 returns per second.

The first function of the Bermuda site is to back up the Goddard 7090's and the Mercury Control Center in making the GO, NO-GO decision. If the Mercury Control Center does not have sufficient information to make a GO, NO-GO decision and so informs Bermuda, or if Bermuda is unable to learn of the decision made at the Mercury Control Center because of a failure of communications, the Bermuda Flight Dynamics Officer independently makes the GO, NO-GO decision and commands an abort if necessary.

Under normal operating circumstances with all ground systems properly functioning, the Bermuda site independently determines the acceptability of the orbit into which the capsule has been inserted. This determination is accomplished within 25 seconds after capsule separation. Bermuda is in the best position to make this determination since the capsule is well within radar range. Since the Bermuda computer is receiving radar returns at a rate of 10 per second, this determination can be made much more quickly than if the returns were sent to Goddard via teletypewriter for processing. If it turns out that the orbit is not acceptable, the Bermuda 709 calculates and displays the retrofire time settings and the impact points associated with each retrofire setting. If charged with the responsibility (as outlined in par. 2.2.6), the Flight Dynamics Officer commands the re-entry so that the capsule will land in or as near as possible to a predetermined recovery area.

2.3 ABORT

From liftoff through insertion it may become necessary to abort the mission. Generally speaking, three types of situations may call for abort:

a. Catastrophic conditions in the capsule or launch vehicle.

b. Physical condition of the astronaut.

c. Improper trajectory or velocity.

The Launch Monitor Subsystem is primarily concerned with abort situations resulting from improper trajectory or velocity figures and plays a key role in the event of abort for any reason. For all aborts occurring later than 25 seconds after liftoff, the Launch Monitor Subsystem provides prediction of impact position and time. The decision to abort for reasons of trajectory would be based on information continuously provided by the Launch Monitor Subsystem during the launch phase.

If it is necessary to abort the mission prior to 25 seconds after liftoff, the IP 709 Complex is relied on to supply the impact prediction. The IP 709 Complex normally supplies this information to the Cape Canaveral Range Safety Officer. A representative of the Range Safety Officer is present at the Mercury Control Center and receives a voice message giving the position and time of landing if an abort occurs this early in launch. The recovery forces use this information in directing the recovery of the capsule.

The decision to abort the mission because of improper trajectory or velocity is the prime responsibility of the Flight Dynamics Officer at the Mercury Control Center. The decision to abort or not to abort is based on information displayed on the Flight Dynamics Officer's Console and on Plot Boards I, II, and III.

The lines of information transfer and the radar sources of data during an abort situation are the same as during normal launch and insertion activities. The timing and structure of the high-speed messages arriving at and leaving from Goddard remain the same. The only difference in information transfer is in the contents of certain portions of the messages originating at Goddard. The programs in the Goddard computers are constantly being advised of the status and phase of the mission by the telemetry information that is common to all high-speed messages transmitted from Cape Canaveral. The state of certain bit positions of this telemetry information indicates whether an abort has been initiated and informs the computers how far the mission has progressed. As soon as the Goddard 7090's sense that an abort has been initiated, the information sent to Plot Boards I and II is changed to conform to abort requirements. Plot Board I shows velocity and the height of the vehicle above spherical earth, while Plot Board IV displays the latitude and longitude of present position and latitude and longitude of the predicted impact position.

Other plot boards and consoles at the Mercury Control Center are continually displaying information directly related to a possible abort throughout the launch portion of the mission. This information forms the basis for the decision to abort for trajectory or velocity reasons and the subsequent decision of the proper time to abort. The question of when to abort depends on several flight characteristics supplied by the Launch Monitor Subsystem. If an abort occurs late in the launch phase when the velocity attained is nearly orbital and the altitude is nearly maximum, the time for using the retrorockets must be considered. The time for firing the retrorockets in such a situation is critical since this determines whether the capsule will land in a predetermined recovery area. For this reason, the impact positions associated with different delays in firing the retrorockets are continuously displayed throughout the launch phase. Table 2-1 gives a summary of the display quantities (including those that are concerned with the abort situation) provided by the Goddard computers. The symbols and terms used in this summary are defined in Appendix A.

For an abort occurring late enough to require the use of the retrorockets, the Goddard Complex receives teletypewriter messages from the Bermuda installation, the mid-Atlantic ship, and the Canary Island tracking site. Except for the Atlantic ship, these messages consist essentially of time, raw radar returns of range, azimuth and elevation, and a station identity code; the Atlantic ship receives telemetry and voice from the capsule, but has no radar. Bermuda sends data smoothed by the IBM 709 computer as well as raw radar returns. All three sites transmit the messages at a rate of 10 per minute. The Goddard computers derive the pertinent display quantities and transmit them to the Mercury Control Center for distribution and display at the same rate of 10 messages per minute.

Another situation that may be considered an abort is one in which a GO decision has been made but the orbit is determined to be unacceptable by the Bermuda Complex. It may be better termed an early re-entry, but is included here as a logical sequence. The Bermuda computer is receiving radar returns at the time of insertion at a rate of 10 per second. If the capsule is observed to be deviating from an acceptable orbital path or velocity, the Bermuda Flight Dynamics Officer communicates with the Mercury Control Center and, if required, commands the firing of the retrorockets to effect a re-entry. The Bermuda Flight Dynamics Officer has sufficient information displayed to allow him to select the optimum time for firing the retrorockets to assure landing in one of the recovery areas. If this happens, the Goddard computers again depend on Bermuda and the Canary Island site for the track information in exactly the same manner as explained previously. Recovery information again is displayed at the Mercury Control Center as received from Goddard.

2.4 ORBIT

While the capsule is orbiting around the earth, the Launch Monitor Subsystem processes information that it receives from the world-wide network of tracking stations and presents the derived quantities for display at the Mercury Control Center. All the computations during this phase of the mission are performed by the 7090 computers at the Goddard Space Flight Center. To help the tracking stations perform their tracking function, the Goddard computers transmit a series of acquisition messages to each tracking site as the capsule approaches the site.

Since certain tracking stations are not equipped with radar, the messages arriving at Goddard during orbit vary in content, depending on which tracking station is in contact with the capsule. The following sites are not equipped with radar:

a. Atlantic Ocean Ship

b. Kano

c. Zanzibar

d. Indian Ocean Ship

e. Canton Island

f. Grand Turk Island

The remainder of the tracking stations are equipped with either C band or S band radar or both. As a given radar-equipped site acquires the capsule and receives valid radar returns, it begins to transmit messages to the Goddard computing center. These raw radar returns are transmitted 10 times per minute to Goddard by means of teletypewriter. The format and content of all teletypewriter messages generated by radar-equipped sites is constant. The track information in these messages consists of radar fixes of range, azimuth, and elevation. In addition to these quantities, characters indicating the kind of data, station identity, radar type, data validity, and the time at which the track information was valid are included in the messages. Each message is 34 characters in length and is transmitted at a standard rate of 360 characters per minute.

With the exception of White Sands and Eglin, all the tracking stations are equipped with telemetry receivers and receive telemetry event returns whenever the capsule is in range. All the tracking stations except Cape Canaveral transmit a teletypewriter summary of the telemetry events to Goddard after the capsule passes out of range. This telemetry summary includes a number of items that are not descriptive of the flight characteristics of the capsule. These are items describing the environmental condition of the capsule and aeromedical data and are not used by the Launch Monitor Subsystem as a basis for any computations. The complete telemetry summaries, however, are relayed via teletype from Goddard to the Mercury Control Center for information purposes. A number of operational parameters extracted from these messages at Goddard do enter into the computing system. These are the elapsed capsule times (ECT), the GMT of reading, and the retrofire setting (ECTRS). These items are manually inserted into the Goddard computers by means of paper tape readers connected to the Data Communications Channel.

During the orbital passes over the Cape, this site is unique in performing as a tracking station. The raw radar returns are transmitted to Goddard in the normal manner, the difference being in the manner in which the telemetry event information is sent to Goddard. This is done in exactly the same fashion as during the launch phase. The telemetry information is relayed to Goddard by way of the high-speed buffer and retransmitter located in the IP 709 building. The message is a high-speed message transmitted at a rate of 1000 bits per second. As during launch, the entire message format is 384 bits in length, but the only useful information is contained in the first 72 bits, which contain the telemetry information. The remainder of the message contains 0's with 1's in specified positions to denote "no data" and to keep Goddard receivers in synchronization. This message is repeated every 400 milliseconds. Since telemetry is transmitted on high-speed lines from Cape Canaveral, this station does not send a telemetry summary message.

Based on the inputs from the world-wide tracking stations, the Goddard Complex makes several computations to derive display and acquisition data. The acquisition messages give a prediction to the tracking stations as to where and when they can expect to acquire the capsule initially. To do this, the messages are sent to the sites 45, 25, and 5 minutes before the capsule crosses the radar horizon. The message contains the range, azimuth, and elevation for capsule positions of 1° above the horizon, 10°, 30°, and the time associated with each of these positions. A fourth set of data in these acquisition messages predicts the position of the capsule 10 seconds after it has made its closest approach to a site. These acquisition messages are used by the tracking stations to position all antennae, including both radar and telemetry. All acquisition messages are sent by teletypewriter to the tracking stations.

The remaining orbital computations at Goddard supply certain display quantities for use at the Mercury Control Center. The orbit programs are continually defining and refining the orbit. The Goddard computers derive suitable display quantities descriptive of the capsule's velocity, its altitude, its position, and quantities showing the eccentricity and inclination of the orbit. In anticipation of a possible early re-entry, the Goddard computers continuously calculate various retrofire settings, and impact positions associated with the next upcoming recovery area. In addition to these quantities, the Mercury Control Center receives a number of different time figures associated with capsule clock settings and elapsed times. The summary of Control Center displays in Table 2-1 gives all the orbital display quantities and plot boards or consoles on which they are displayed.

The quantities displayed at the Mercury Control Center during orbit arrive at Cape Canaveral over high-speed lines. The internal allocations and bit rate of the messages from Goddard are the same as during the launch phase. The structure of these messages is shown in figure 2-3; the repetition rate is once every 12 seconds. The Goddard Complex receives its track information at a rate of one every six seconds, but sends only the latest information to the Control Center.

2.5 RE-ENTRY

The return of the capsule from orbit is considered a normal re-entry if it occurs at the end of the third orbit and if the capsule lands in a predetermined recovery area. Any return of the capsule from orbit before this planned time is considered an early re-entry. The function of the Launch Monitor Subsystem remains the same during either type of re-entry. The subsystem, however, is obliged to operate in a way dictated by the location of the capsule at the time of retrofire. That some of the tracking stations are not equipped with radar indicates that during an early re-entry the Goddard computers may not be receiving current rate and track information.

2.5.1 Normal Re-entry

As the capsule approaches the end of the third orbit, the firing of the retrograde rockets is commanded. The messages arriving at the Goddard Space Flight Center arrive via teletypewriter and are of the same format and rate as the messages during the orbit phase. The telemetry summary from the tracking station informs the Goddard Complex that the retrorockets have fired and the time at which they were fired. This information is fed into the 7090's by means of the paper tape readers, and the re-entry computations begin immediately. All the tracking stations between the point of retrofire and ultimate landing area are equipped with radar. There are seven such sites so that the re-entry routines operate practically continuously on current rate and track data.

The Goddard computing center is the sole source of display data for the Mercury Control Center during the re-entry phase. The consoles and plot boards at the Mercury Control Center which are concerned with re-entry and recovery are updated 10 times per minute during this phase. The summary of display quantities supplied by Goddard in Table 2-1 shows the active displays and the information on each. The messages arrive at the Control Center over the high-speed data network from Goddard. The displayed information consists essentially of GMT of landing (computed), recovery area, velocity, altitude, and latitude and longitude of the predicted impact and present positions.

The Canaveral radar, telemetry receivers, IP 709 buffer, and teletypewriter transmitters are active during a normal re-entry. The telemetry information is transmitted to Goddard through the IP 709 buffer and high-speed retransmitter.

It is important that the switch on the buffer be in the PROCESSED position. This transmission of telemetry is repeated once every 400 milliseconds. The Cape radar transmits raw returns of range, azimuth, and elevation to Goddard via the teletype transmitter located in the Mercury Control Center.

2.5.2 Early Re-entry

As mentioned before, the role of the Launch Monitor Subsystem is the same during an early re-entry as during a normal re-entry. The data available to the Goddard computers depends on where in the orbital path the re-entry is initiated by the firing of the retrorockets. If the tracking stations along the descent route are radar-equipped, the subsystem is supplied with current rate and track data as in the case of a normal re-entry.

It is possible that capsule environmental conditions or the physical condition of the astronaut may require a re-entry under other than optimum conditions. The Launch Monitor Subsystem is required to perform with a limited supply of data for abnormal re-entry situations. Under these conditions, the 7090's at Goddard must operate on stored data and base their computations and predictions on projected nominal values of re-entry trajectory. If the capsule is not in the range of a command station at the time a re-entry becomes necessary, the astronaut himself initiates the retro-events. The time of retrofire is then sent to Goddard as soon as possible for entry into the computers.

The information computed at Goddard for display is sent to the Mercury Control Center at the normal rate of 10 per minute via the high-speed network.

CHAPTER 3

FLIGHT CONTROLLER USE OF LAUNCH MONITOR SUBSYSTEM DATA

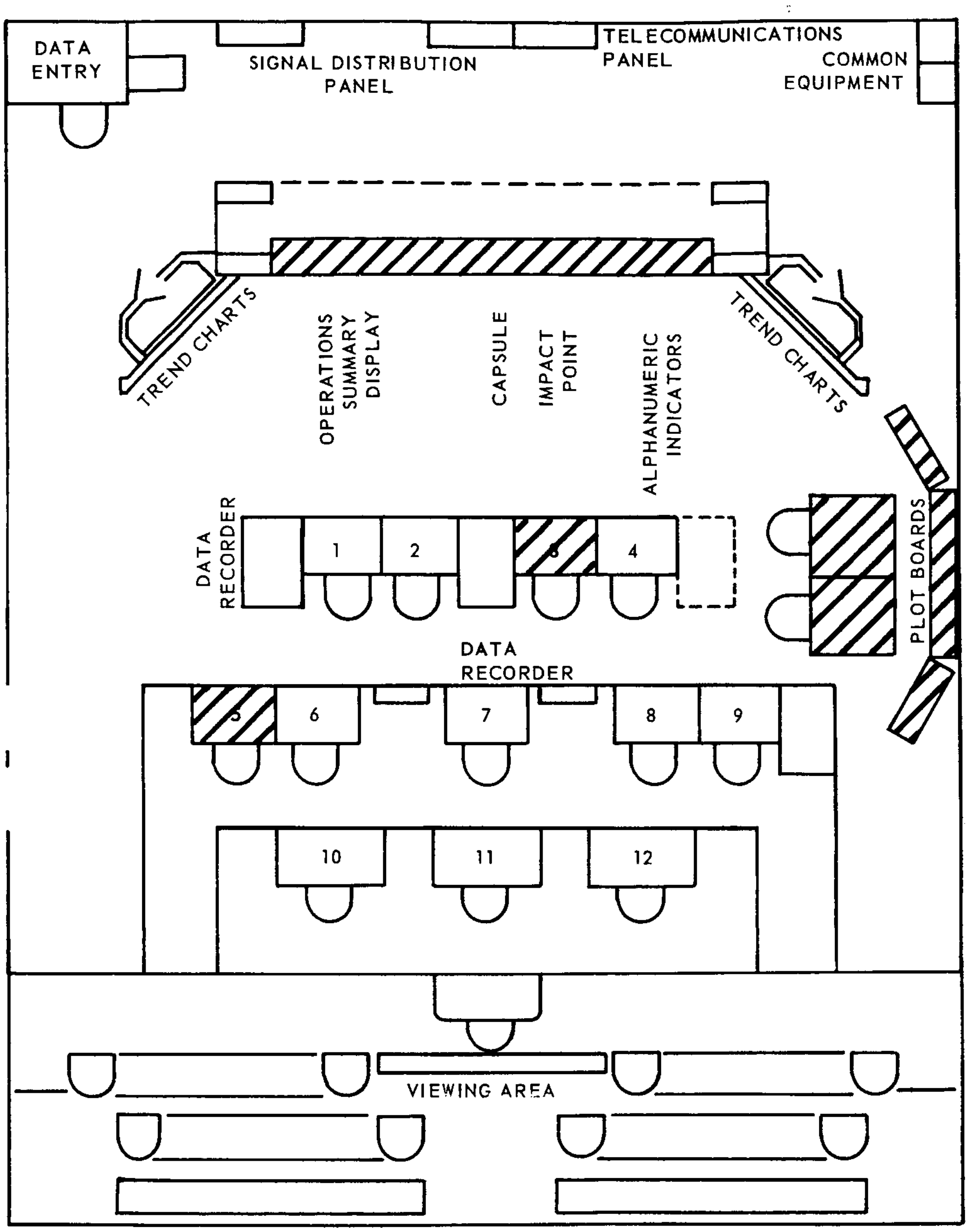
All personnel in the operations area of the Mercury Control Center (MCC) at Cape Canaveral and the Control Center at Bermuda can observe some of the output of the Launch Monitor Subsystem. Certain Control Center personnel, however, have direct contact with the subsystem and are responsible for making decisions based on Launch Monitor Subsystem data. The duties of these Flight Controllers and their relationship to the Launch Monitor System are described below. The layout of the Mercury Control Center at Cape Canaveral is shown in Figure 3-1.

Situated in front of the Flight Controllers' area at the Mercury Control Center is a wall map of the earth 26 feet wide by 8 feet high (Fig. 3-2). It is visible to observers and visitors in the viewing area as well as to the Flight Controllers. Its chief purpose is to provide a visual representation of the progress of the Mercury mission after completion of the launch phase. The expected orbital path of the capsule is drawn on the map. After launch, a diminutive capsule appears on this path to indicate the present position of the real capsule in its orbit. In advance of the capsule position is a small circle indicating the impact point if the retrorockets are fired instantly. The location of the range stations and recovery areas is identified on the map, with a color-coded indication of the status of each. Capsule-station contact is signified by a flashing ring of light surrounding the appropriate station.

Immediately above the wall map are several digital displays. Some of the information for these displays is furnished by the Goddard 7090's. This information includes orbit number and ground time remaining until retrofire occurrence. Capsule position and impact point (wall map data) are also provided by the 7090's. The range station and recovery status indicators are controlled by Mercury Control Center personnel.

3.1 FLIGHT DYNAMICS OFFICER

The Flight Dynamics Officer's evaluation of flight characteristics covers the entire course of the mission. His primary function is to monitor flight parameters and thus evaluate deviations from the flight path and insertion of the capsule into orbit. Figure 3-3 shows the Cape Canaveral FDO console. Figure 3-4 illustrates the information displayed on the four plot boards used by the Flight Dynamics Officer and the Retrofire Controller.



Launch Monitor Subsystem Related Displays and Consoles

1 FLIGHT SURGEON
2 CAPSULE ENVIRONMENT MONITOR
3 CAPSULE COMMUNICATIONS
4 CAPSULE SYSTEMS MONITOR
5 RECOVERY STATUS MONITOR
6 RANGE SAFETY OFFICER
7 FLIGHT DIRECTOR
8 VEHICLE SYSTEMS MONITOR
9 VEHICLE TELEMETRY MONITOR
10 RECOVERY DIRECTOR
11 OPERATIONS DIRECTOR
12 NETWORK COMMANDER
13 RETROFIRE CONTROLLER
14 FLIGHT DYNAMICS OFFICER

FIGURE 3–1. LAYOUT OF MERCURY CONTROL CENTER

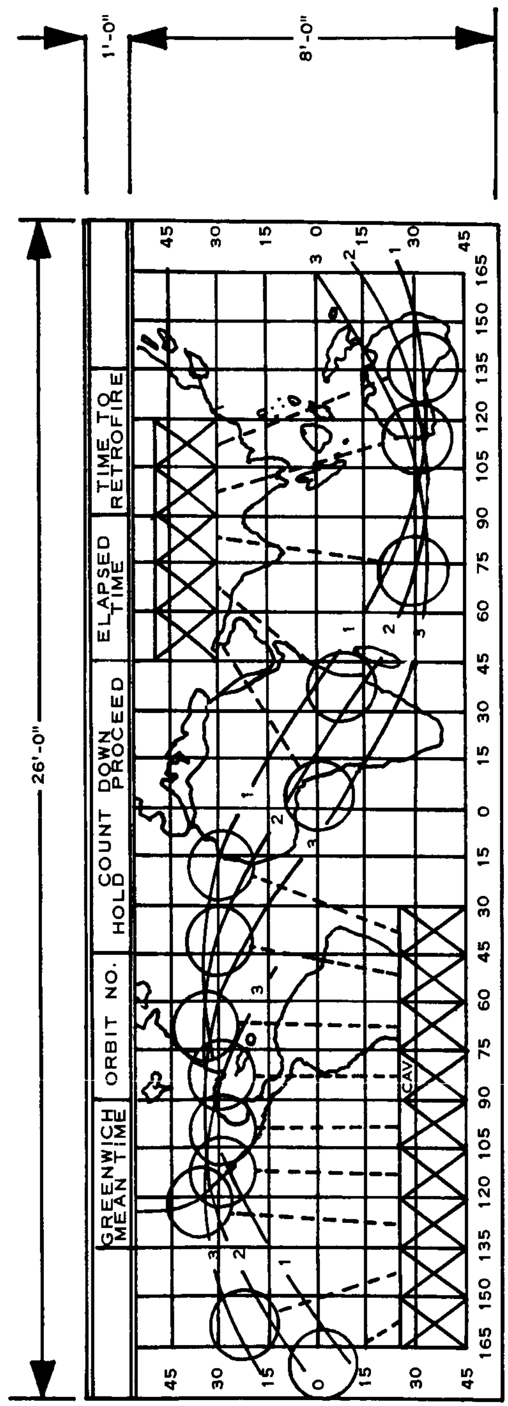


FIGURE 3-2. WALL MAP, MCC

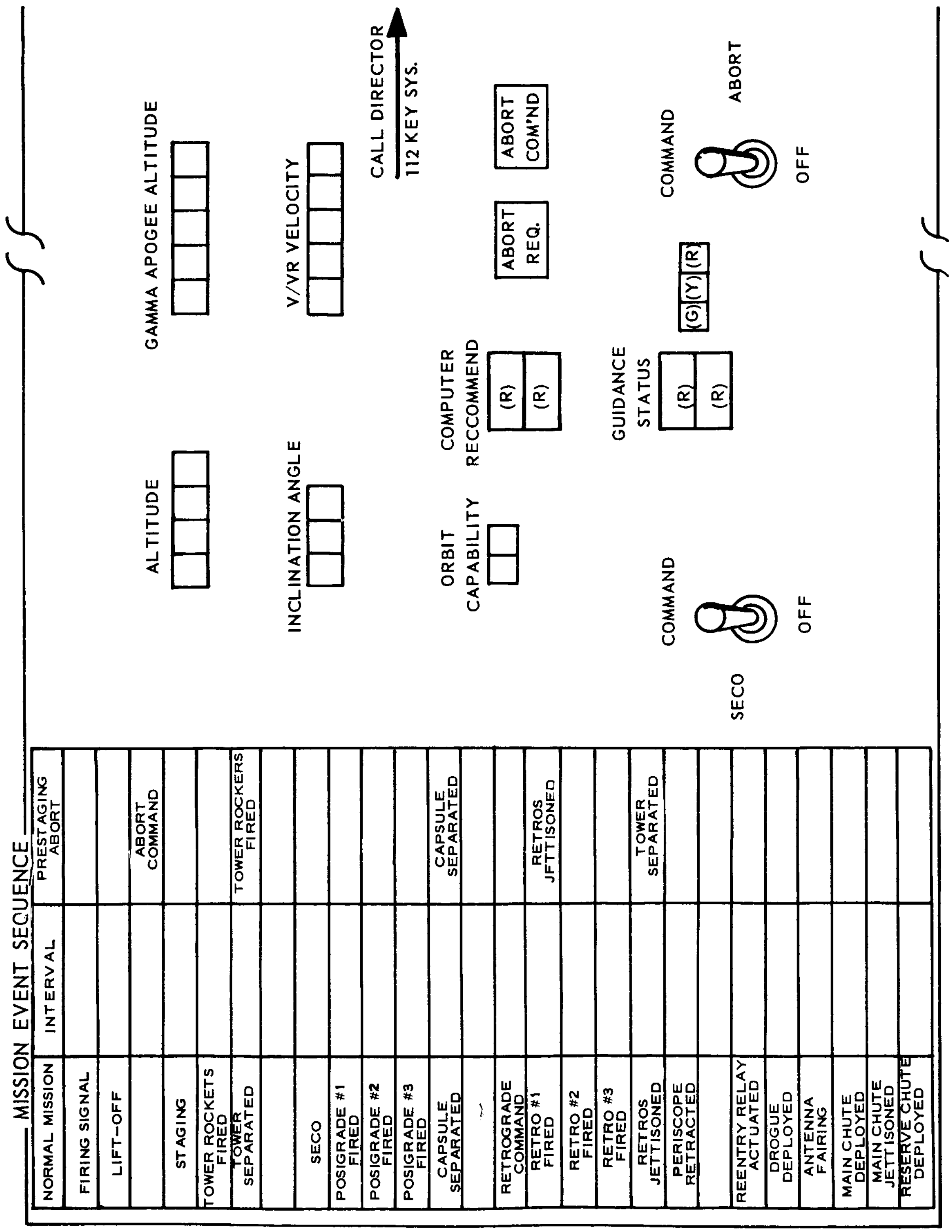


FIGURE 3-3. FLIGHT DYNAMICS OFFICER, MCC

3.1.1 Launch

During the first minutes following liftoff, the Flight Dynamics Officer monitors Plot Boards II and III. Plot Board II shows capsule altitude and cross-range deviation vs down-range distance; Plot Board III shows velocity and acceleration vs elapsed time. Information for Plot Board II is furnished by the Burroughs-GE guidance system either directly or as processed by Goddard's 7090 computers, while there is a direct Burroughs-GE input to Plot Board III throughout launch and insertion. Taking these plotted values into consideration, the Flight Dynamics Officer decides whether the deviations from the nominal are so great that guidance cannot correct the launch vehicle path to within acceptable limits in the available time and also whether adequate velocities can be expected at BECO and SECO.

If an abort situation is indicated, the Flight Dynamics Officer selects the abort time, commands abort, and informs the appropriate flight personnel of his decision. If he decides on continuation of the mission, he monitors the BECO signal and calls out its occurrence to the Flight Director and Bermuda. If BECO does not occur within five seconds after nominal time, abort is commanded.

Following BECO, Plot Boards I and III are monitored. Plot Board I receives its input from Burroughs-GE either directly or as processed by the 7090's. It displays flight path angle (γ) vs velocity ratio (V/V_R) whereas Plot Board III now displays yaw velocity and predicted height of insertion vs time to go until SECO. For normal flight, γ should approach 0^o as V/V_R approaches 1, yaw velocity should approach 0, and predicted height of insertion should approach 105 N. miles. These values are verified by cross-checking with the appropriate digital displays on the console.

The Flight Dynamics Officer considers all these values in judging whether guidance can maintain or correct the missile path and whether adequate velocities can be expected at SECO. If he decides an abort is required, he proceeds as explained.

In anticipation of an early re-entry, the Flight Dynamics Officer monitors Plot Board IV. At this stage of the mission, Plot Board IV displays 7090 data showing latitude (ϕ) and longitude (λ) of impact point (IP) for retrofire in 30 seconds and at maximum delay.

3.1.2 Insertion

Insertion is evaluated by observing the GO, NO-GO computer recommendations and information displayed on Plot Boards I and III and the console. On Plot Board I, γ is plotted against V/VR and must meet or exceed the 1-1/2 orbit limit. Insertion altitude on Plot Board III and orbital inclination on the console are observed. These values must reside within tolerable limits. On the basis of these data, the Flight Dynamics Officer makes the GO, NO-GO decision

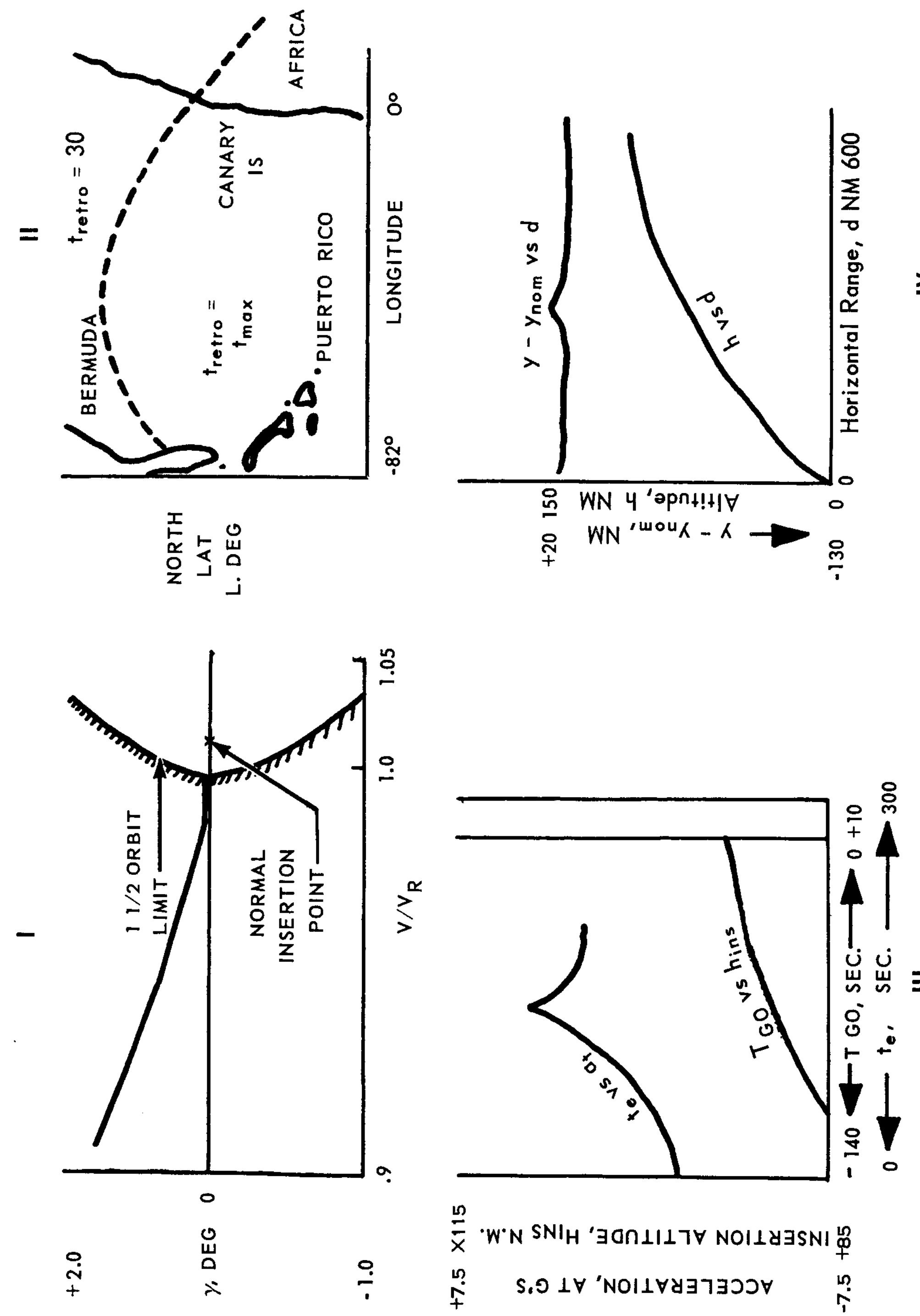


FIGURE 3-4. TYPICAL PLOT BOARD DISPLAYS, MCC

and announces it to the Operations Room and Bermuda within 10 seconds after SECO.

3.1.3 Orbit and Re-entry

Following insertion, the Flight Dynamics Officer observes the orbital parameters on the console and compares them with desired values. He confers with the appropriate flight controllers concerning orbit capability and makes recommendations on flight duration to the Flight Director.

The chart on each plot board is changed for this mission phase, and all plot boards now receive 7090 data. Plot Boards I, II, and III are then monitored to aid in the evaluation of orbit capability. Plot Board I now displays capsule height vs inertial velocity, Plot Board II displays capsule height and semimajor axis minus average radius of earth vs elapsed time, and Plot Board III displays longitude of perigee and eccentricity vs elapsed time. Plot Board IV, which displays ϕ of IP in 30 seconds and λ of P vs ϕ of IP in 30 seconds and λ of PP, is monitored in preparation for the possibility of an early re-entry.

During re-entry, the Flight Dynamics Officer works in conjunction with the Retro-Controller and makes recommendations to compensate for any deviations in the flight plan.

3.2 RETROFIRE CONTROLLER

The primary function of the Retrofire Controller (RFC) is to maintain the appropriate capsule clock setting which controls the time of retrofire. As more recent data is computed, the setting is changed by direct radio command when the capsule is within range of Cape Canaveral or by instructions to a remote station which is within range. If sufficient time is not available to reset the clock, he may use a retrocommand control or instruct the astronaut to initiate retrofire. His console is equipped with digital time displays and recovery area displays pertinent to each phase of the mission. The information for these displays is provided by the 7090 computers at Goddard. (See Figs. 3-4 and 3-5.)

3.2.1 Launch

Following tower separation, the Retrofire Controller observes the nominal time (ΔT) before the retrorockets can be fired to achieve impact in the next designated recovery area. He also monitors the plot boards and the Flight Dynamics Officer's judgment of mission progress in preparation for a possible abort.

If abort is commanded, he observes Plot Board IV, which displays latitude and longitude of IP for retrofire in 30 seconds and at maximum delay. The recovery area is noted, and its relationship to the impact points observed on

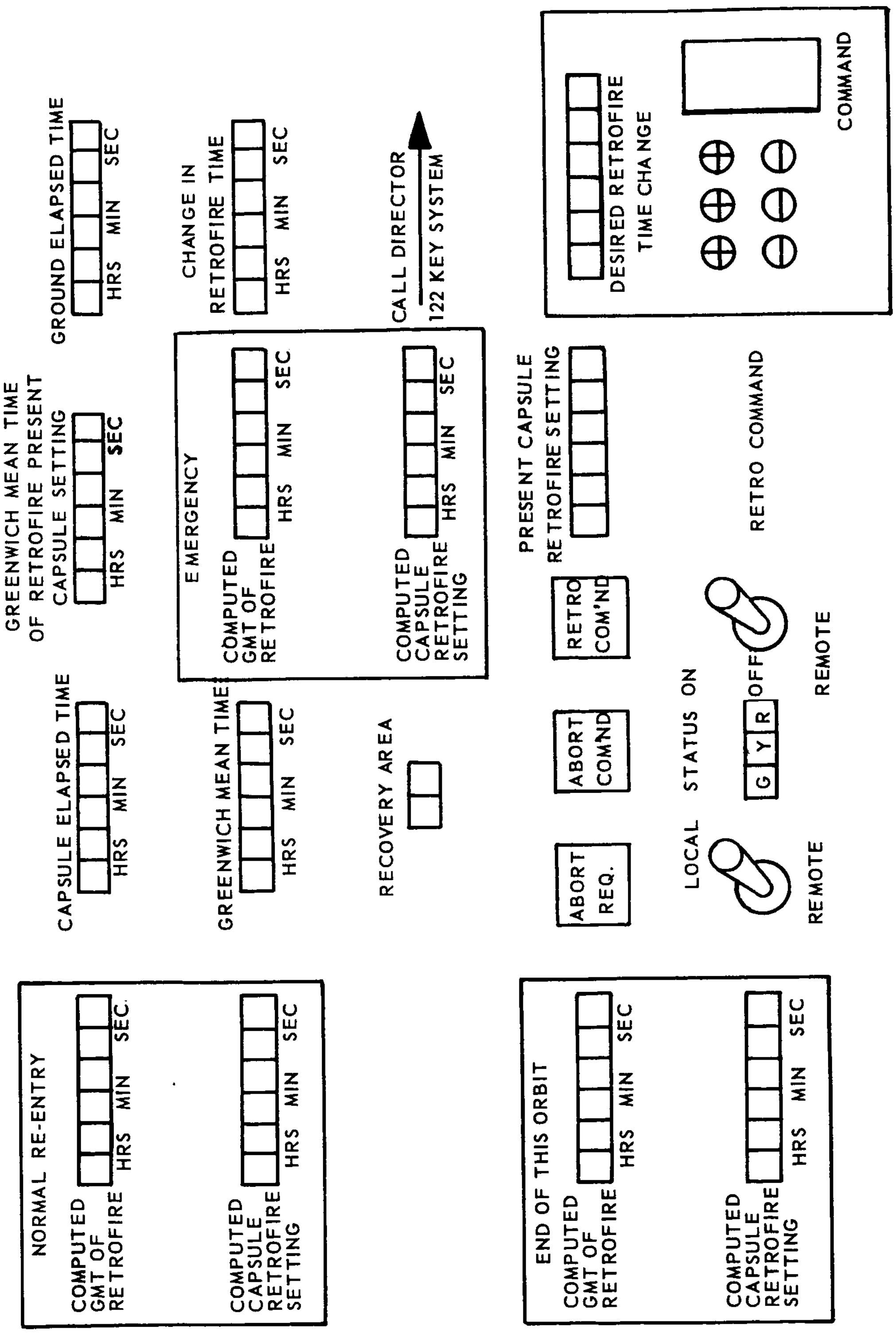


FIGURE 3-5. RETROFIRE CONTROLLER'S CONSOLE, MCC

the plot board is determined. He compares the capsule elapsed time with the computed capsule retrofire setting and observes the change in retrofire time. If time is available, he inserts the change in retrofire time into the desired retrofire time change. If no time remains, he monitors both the computed GMT of retrofire and the actual GMT. When these values match, he initiates the retrofire sequence.

3.2.2 Orbit and Re-entry

When the capsule achieves orbit, the Retrofire Controller continues to monitor both Plot Board IV and the console and thus maintain accurate setting of the capsule clock. During the third orbit, when the capsule is approaching the Hawaii Command Station, he sends the final change in retrofire time message. He then monitors the ground elapsed time displays and reports the reading as required by the Operations Room.

3.3. RECOVERY STATUS MONITOR

The chief duties of the Recovery Status Monitor (RSM) are to convey impact prediction data to Recovery Headquarters and to inform Operations Room personnel of the status of the recovery groups.

To enable him to perform his functions, the Recovery Status Monitor is provided with a console that displays digital data computed by the 7090's at Goddard. (See fig. 3-6.) This information consists of GMT of landing and the latitude and longitude of the landing point for the appropriate mission phases. The Recovery Status Monitor monitors this data and conveys it to the Recovery Officer during abort, orbit, and re-entry, when requested to do so. In addition, he receives status reports from the recovery units which he reports to the Operations Room.

3.4 FLIGHT DYNAMICS OFFICER - BERMUDA

3.4.1 General

As a backup to the Cape Canaveral Flight Dynamics Officer, the Bermuda Flight Dynamics Officer independently evaluates the launch trajectory and insertion parameters. If Cape Canaveral is unable to evaluate these parameters or if communications fail so that he is unaware of the decision made at the Mercury Control Center, the Bermuda Flight Dynamics Officer assumes control and makes the GO, NO-GO decision. If the decision is negative, he also assumes the Retrofire Controller's functions. (See Fig. 3-7.)

3.4.2 Launch

Following the liftoff announcement from Cape Canaveral, the Bermuda Flight Dynamics Officer communicates with the Cape Canaveral Flight Dynamics Officer

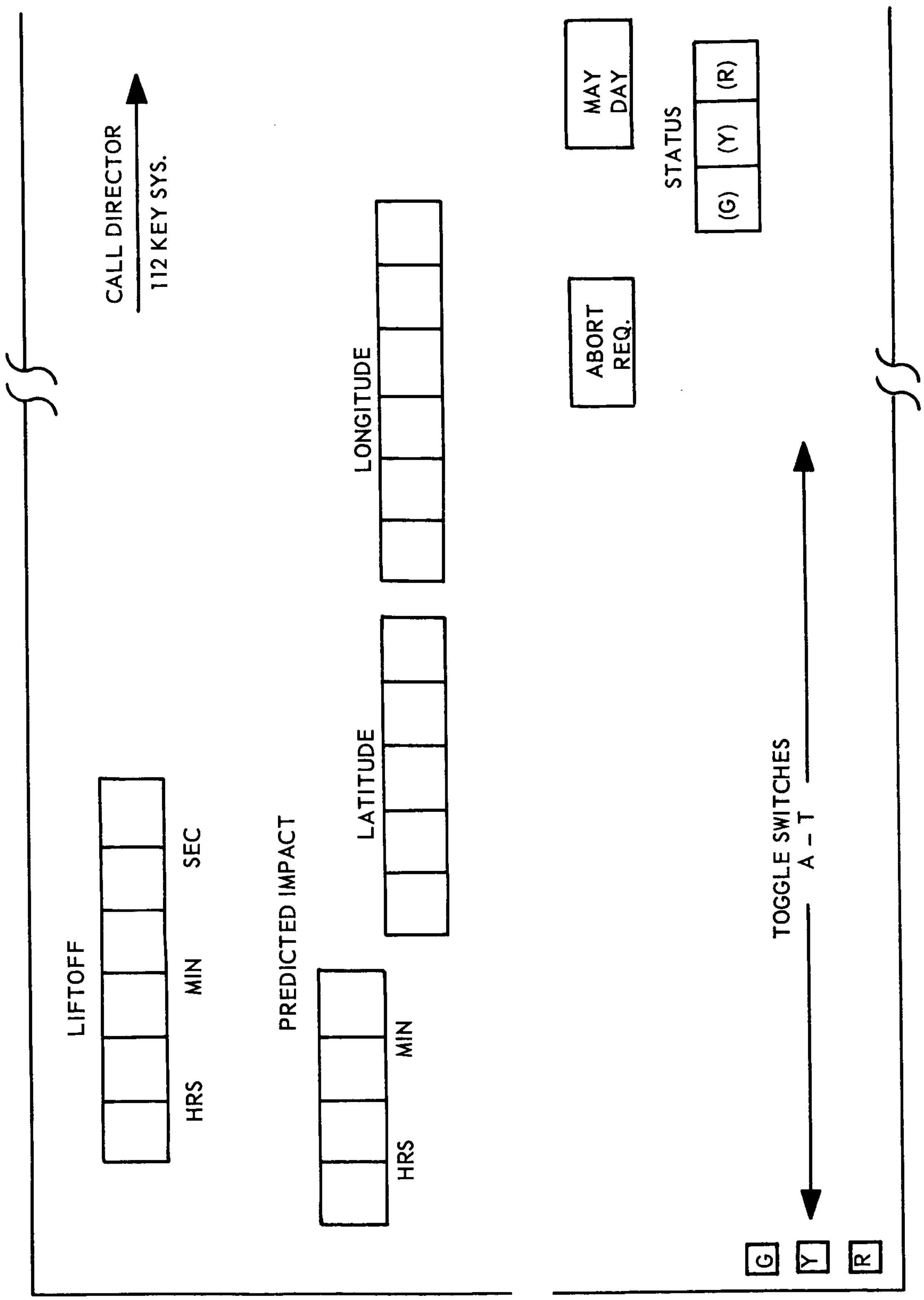


FIGURE 3–6. RECOVERY STATUS MONITOR CONSOLE, MCC

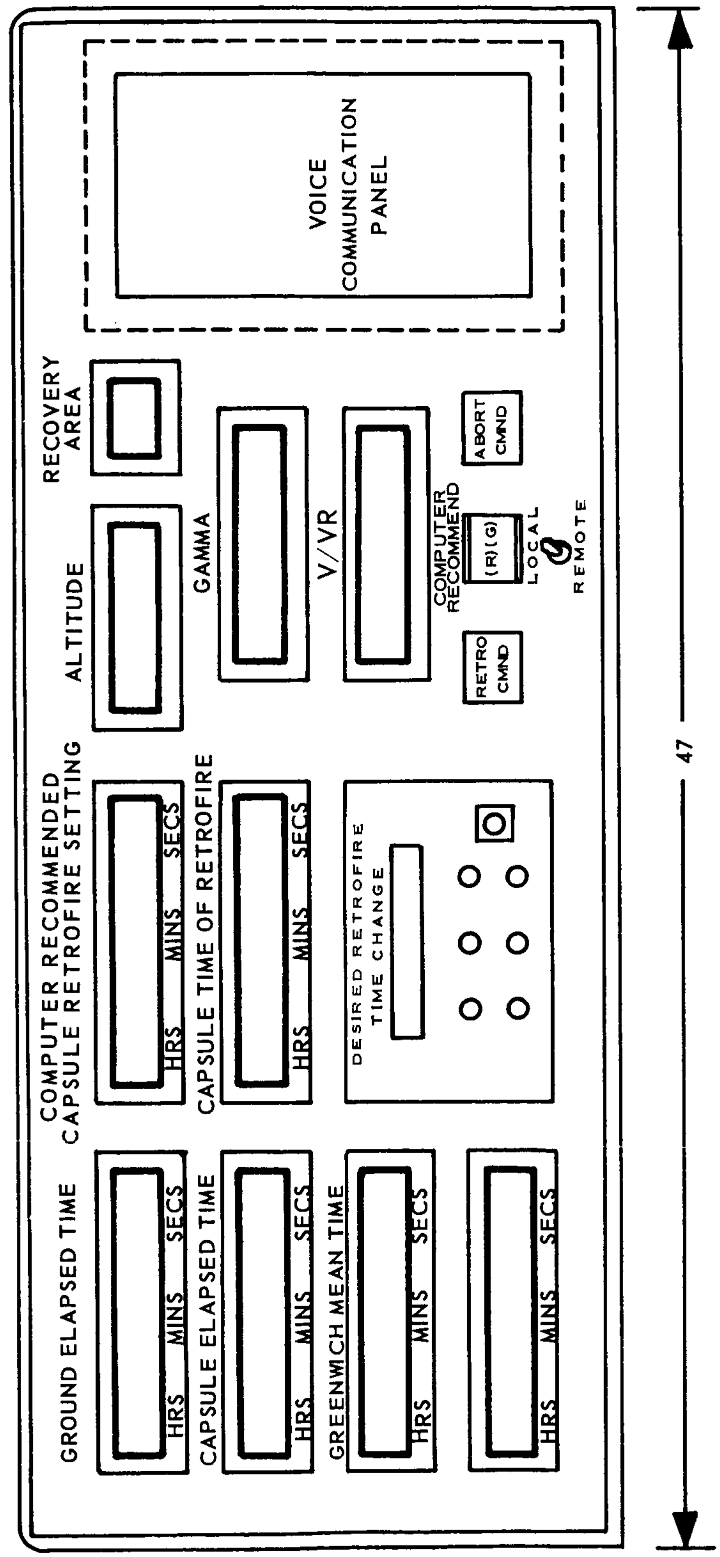


FIGURE 3-7. FLIGHT DYNAMICS OFFICER'S CONSOLE, BERMUDA

concerning mission progress and MCC data quality. Upon acquisition of the capsule by the Bermuda radar, he observes values on the plot board and console to evaluate the launch trajectory. At this time, the plot board displays velocity ratio (V/V_R), flight path angle (γ), and impact point (IP) for retrofire in 30 seconds. Discrete console displays are V/V_R, γ, capsule altitude, and the computer recommendation (GO, NO-GO). All displays are furnished with IBM 709 processed data.

If the decision is made to transfer control to Bermuda because of unacceptable data at the Mercury Control Center or communications failure, the Bermuda Flight Dynamics Officer evaluates the insertion parameters by observing the GO, NO-GO computer recommendation with plot board and console information. On the plot board, γ is plotted against V/V_R and must meet or exceed the 1-1/2 orbit limit. Insertion altitude is observed on the console. The GO, NO-GO decision is made on the basis of these data and announced within 10 seconds after SECO.

If the decision is negative, the Flight Dynamics Officer observes the latitude and longitude of IP for retrofire in 30 seconds. He notes the recovery area on the console and observes its position relative to the impact points. If time is available to reset the capsule clock, he does so. If insufficient time remains, he monitors the computed GMT of retrofire and the actual GMT. He initiates the retrofire sequence when these two values are equal.

CHAPTER 4

LAUNCH MONITOR SUBSYSTEM, UNIT OPERATIONAL USE

This chapter describes the operational use and purpose of each equipment unit in the subsystem, the system traffic delays imposed by some of these units, and the operator procedures for control of the subsystem. The descriptions are intended to impart a general knowledge of the function of the units and the manner in which they contribute to system functioning. Except in the case of the consoles provided for control of the subsystem, operating procedures for the equipment units are not discussed in detail here since these procedures are available in other documents.

SECTION 1

DESCRIPTION OF EQUIPMENT UNITS

The operational use of equipment units is described in terms of the function of the unit, operation and description of the unit, inputs, outputs, and the effects of unit malfunction on the system. Descriptions are grouped according to site in the following order:

Burroughs-GE Complex
IP 709 Complex
Mercury Control Center
Goddard Computer Center
Bermuda

1.1 EQUIPMENT AT CAPE CANAVERAL

1.1.1 Model 71 High-Speed Buffer and Dual Data Retransmitter

1.1.1.1 Function

Telemetry data and data processed by the Burroughs-GE Complex must be transmitted to the IBM 7090 Complex at Goddard for further processing and also directly to the Mercury Control Center for display. (See fig. 4-1.) These data are transmitted over high-speed data lines. To facilitate the data transmission, the High-Speed Buffer and Dual Data Retransmitter performs the following functions:

a. Accepts and time-buffers d-c digital data in parallel format from the Burroughs computer.

b. Transmits part of this data to the IBM 7090 Complex at Goddard and the remainder to the Simplex Receiving Register at the Mercury Control Center.

c. Accepts serial data from the Telemetry Event Transmitting Buffer at the Mercury Control Center.

d. Buffers these data and interleaves them with computer data for transmission to the Goddard 7090 Complex.

1.1.1.2 Operation and Description

The Model 71 Data Transmitter consists of a high-speed data receiver, a digital d-c data receiving device, buffering and storage devices, and three data transmitters.

The Burroughs-GE Complex finishes a computational cycle every 497 ±100 ms and then indicates to the data transmitter by an output-reset pulse that it is ready to furnish new data to the system. Upon receipt of such a signal, the data transmitter starts transmitting data to Goddard. The first 72 bits of data are telemetry information received and stored during the previous cycle. While the telemetry data is being transmitted, the Burroughs-GE data is received and stored, ready for transmission at its assigned place in the format. Telemetry data is received continuously from the Telemetry Event Buffer, a complete message being received every 74 ms. Input gating of this data starts 232 ms after the receipt of the output-reset pulse, and sensing for the telemetry end-of-message indication starts 312 ms after receipt of the output-reset pulse. When the end-of-message indication is received, the telemetry input gate is closed and the data is stored for transmission during the following cycle. Transmission of data to the Mercury Control Center starts 108 ms after receipt of the output-reset pulse.

In the absence of a reset pulse from the computer for a period greater than 600 ms, the data transmitter transmits available data. In the absence of telemetry data, computer data and identity are transmitted in the standard format and an indication is given that telemetry data is not available.

1.1.1.3 Inputs

1.1.1.3.1 Computer Inputs

There are 24 parallel input lines, which accept eight 24-bit words, twelve 10-bit words, and one 8-bit word every 497 ±100 ms. Two separate control lines indicate when the computer is ready to furnish new information (output-reset

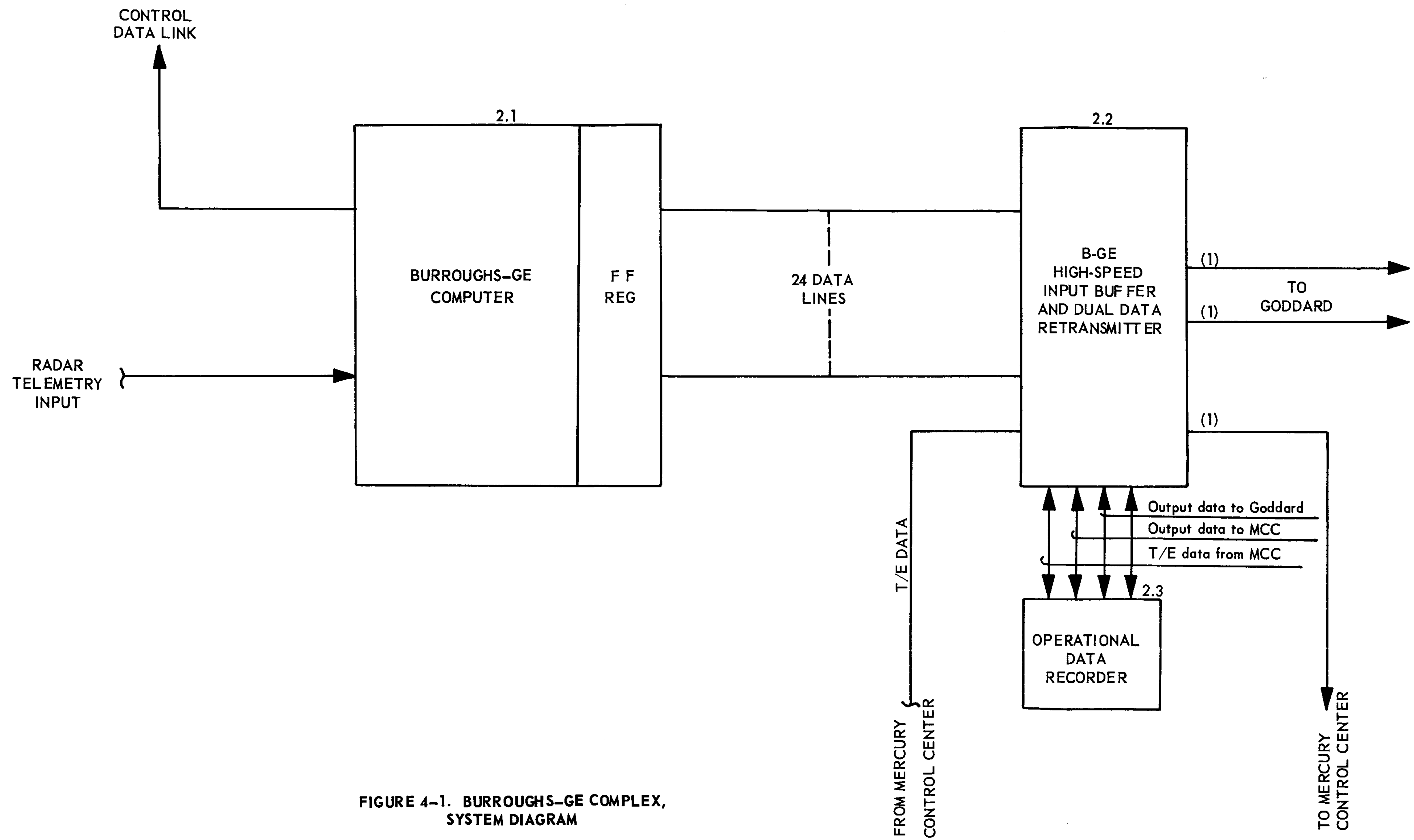


FIGURE 4-1. BURROUGHS–GE COMPLEX, SYSTEM DIAGRAM

pulse) and when a new word is present on the output lines (output-read pulse).

1.1.1.3.2 Telemetry Input

Telemetry data arrives over a high-speed data line in serial format at a rate of 1000 bits per second. Complete messages of 72 bits of data and a 2-ms synchronizing signal are sent continuously. The data is in the form of a 2-kc carrier modulated by 1/2-ms pulses. Synchronizing signals consist of the 2-kc carrier modulated by a 1-1/2-ms pulse, followed by 1/2 ms of no tone.

1.1.1.4 Outputs

Two similar high-speed data lines transmit information to the Goddard IBM 7090 Complex. The same information is transmitted over each line, but not at the same instant; one transmitter delays the transmission. A third output line transmits data to the Mercury Control Center Simplex Receiving Register.

Data output is in serial format in the form of keyed tone bursts of a 2-kc carrier modulated by 1/2-ms pulses. A start-of-message indication, consisting of 2-1/2 ms carrier tone followed by 1/2 ms of no tone, precedes each message. An end-of-message indication, consisting of a 4-1/2-ms carrier tone burst, follows each message.

1.1.1.5 Effects of Malfunction

In the event that the Model 71 Data Transmitter malfunctions, telemetry data and processed radar data can be supplied to the IBM 7090 Complex at Goddard via the IP 709 Complex at Cape Canaveral. This alternate source of data can be switched into service by the Data Selection Supervisor at the Data Quality Monitor Console.

1.1.2 Model 70 Data Transmitter

1.1.2.1 Function

Telemetry data and data processed by the IP 709 Complex or raw radar data from the FPS-16 radar system must be transmitted to the IBM 7090 Complex at Goddard for further processing. (See fig. 4-2.) These data are transmitted over high-speed data lines. To facilitate the data transmission, the Model 70 Data Transmitter performs the following functions:

a. Accepts d-c data in parallel format from the IP 709 computer or raw FPS-16 radar data in serial format from a high-speed data line.
b. Accepts telemetry data in serial format from the Telemetry Event Transmitting Buffer via a high-speed data line.
c. Buffers, arranges in proper format, and retransmits these data in serial format via high-speed data lines to the IBM 7090 Complex at Goddard.

1.1.2.2 Operation and Description

The Model 70 Data Transmitter consists of high-speed data receivers, buffering and storage units, and two high-speed data transmitters.

Two switches on the front panel of the equipment are used to select the proper data source of retransmission to Goddard: the RADAR-PROCESSED switch and the SITE-SELECT switch.

The RADAR-PROCESSED switch is a 2-position rotary switch. In the PROCESSED position, it selects data from the IP 709 computer for retransmission along with telemetry data. Since the computer is the preferred source of data, the switch should normally be in the PROCESSED position, unless the IP 709 is malfunctioning during the launch phase, except as noted in the following paragraph. In the event of malfunction during launch, the switch should be moved to the RADAR position. Raw radar data is then selected for retransmission to Goddard, along with telemetry data. A different transmission format is utilized in this mode. Transmission of raw radar data is indicated by means of a 1 in the first bit of the ID word.

The IP 709 will as first priority base its output on the Azusa beacon, which tracks the vehicle. After SECO, the switch should therefore be turned to the RADAR position so that FPS-16 data, which tracks the capsule, will be sent to Goddard. After the orbit phase begins, the radar data from the FPS-16 radar complex is sent to Goddard via teletype, and only the telemetry data is sent via the high-speed data transmitter. Because the Goddard computer is programmed after the launch phase, to accept these data only in the format produced by the processed mode of operation, the switch must remain in the PROCESSED position after the launch phase has been completed.

The second rotary switch is used to select the appropriate site as the source of radar input when the first switch is in the RADAR position. The five positions of this switch are marked as follows:

Spare
CC-16 (Cape Canaveral)
XN-2 (Grand Bahama)
SS-16 (San Salvador)
Remote

1.1.2.2.1 Processed Mode

Eight 36-bit data words are present on parallel input lines from the IP 709 computer every 200 ms. A signal from the computer indicating that data is available starts transmission of a message to Goddard. The first part of the message consists of telemetry data which was stored in the buffers since the end of the previous transmission. While this is being transmitted, the eight 36-bit words are loaded into the buffer and are ready for transmission at their assigned place in the format. Two hundred ms after the start of transmission (while the output message is still being transmitted) the computer is again ready to present a new message of eight 36-bit words. These words are presented on the input lines, but are not gated into the buffer. Gating in of telemetry data begins 232 ms after start of transmission. Sensing for the end-of-message indication begins 312 ms after start of transmission; receipt of this indication stops the gating in, and a complete telemetry message is then stored, ready for transmission during the next transmission cycle. A complete transmission cycle takes 400 ms and consists of two frames. In the absence of a data-available indication from the computer for more than 400 ms, this unit reverts to a unique transmission mode of 500 ms. The message then consists only of telemetry data, with 1's interspersed throughout the rest of the format to keep receivers at the distant end in synchronization.

1.1.2.2.2 Radar Mode

Raw radar data is received from the FPS-16 radars in serial format over high-speed data lines. A complete message is received every 100 ms. The receipt of every fourth radar end-of-message indication begins a transmission cycle to Goddard. During each cycle, the radar data (range, azimuth, and elevation) is sent four times. Telemetry data is sent once and is received and buffered in the same manner described in the preceding paragraph. In the absence of radar data end-of-message indications, telemetry data is transmitted to Goddard every 500 ms.

1.1.2.3 Inputs

1.1.2.3.1 Computer Inputs

There are 36 parallel input lines from the IP 709 computer. Eight words are transmitted over these lines every 200 ms. A data-available line is conditioned at 200-ms intervals to indicate that the computer is ready to present a new set of eight words. The request-word-transfer line from this unit to the computer is conditioned to request a transfer of one word from the computer. The data-register-loaded line then indicates that the data is actually present on the computer data register and that the input lines are therefore ready to be sampled.

1.1.2.3.2 Raw Radar Input

Raw radar data is received serially from a high-speed data line. A complete message is received every 100 ms and is indicated by an end-of-word indication consisting of 1-1/2 ms of 2000-cycle tone, followed by 1/2 ms of no tone.

1.1.2.3.3 Telemetry Input

Telemetry data is received over a high-speed data line. A complete message consists of 72 bits and is followed by an end-of-word indication consisting of 1-1/2 ms of 2000-cycle tone, followed by 1/2 ms of no tone.

1.1.2.4 Outputs

Two high-speed data lines transmit the output of this unit to Goddard. The same information is transmitted over each line, but a delay of up to 16 ms may be introduced by one transmitter so that the same information is not transmitted simultaneously over both lines. A complete message is sent every 400 ms (or 500 ms if certain input data is lacking).

Different formats are utilized, depending upon whether processed data from IP 709 computer or raw radar data is being transmitted. A message consists of two frames, each preceded by a start-of-message indicator and followed by an end-of-word indicator. A 5-bit identity word in each frame indicates whether the unit is in the processed or radar mode and, if in the radar mode, which radar site has been selected as the input source.

1.1.2.5 Effect of Malfunction

Failure of the Model 70 Data Transmitter would eliminate the IP 709 as a source of data. However, since the Burroughs-GE is the preferred data source during launch, the failure of the model 70 would not be serious unless the Burroughs-GE data source had previously failed.

Failure of the model 70 during the orbit phase would require that Cape Canaveral operating as a range station send a TTY telemetry summary to Goddard.

1.1.3 Model 78 Receiving Register

1.1.3.1 Function

Some data produced by the Burroughs-GE Complex is sent over a high-speed data line to the Mercury Control Center for display at various consoles. (See fig. 4-3.) The Model 78 Receiving Register converts this information from serial, voice frequency, AM signals into parallel d-c format suitable for distribution.

1.1.3.2 Operation and Description

This receiving register unit consists of a device to convert voice frequency signals to d-c levels, a shift register to convert data from serial to parallel format, and storage to store the output until the next complete message is received. In addition, a hold signal is transmitted not less than 1 ms before new data is transmitted to the D/A converters.

A 6-position switch enables the insertion of test data into the registers:

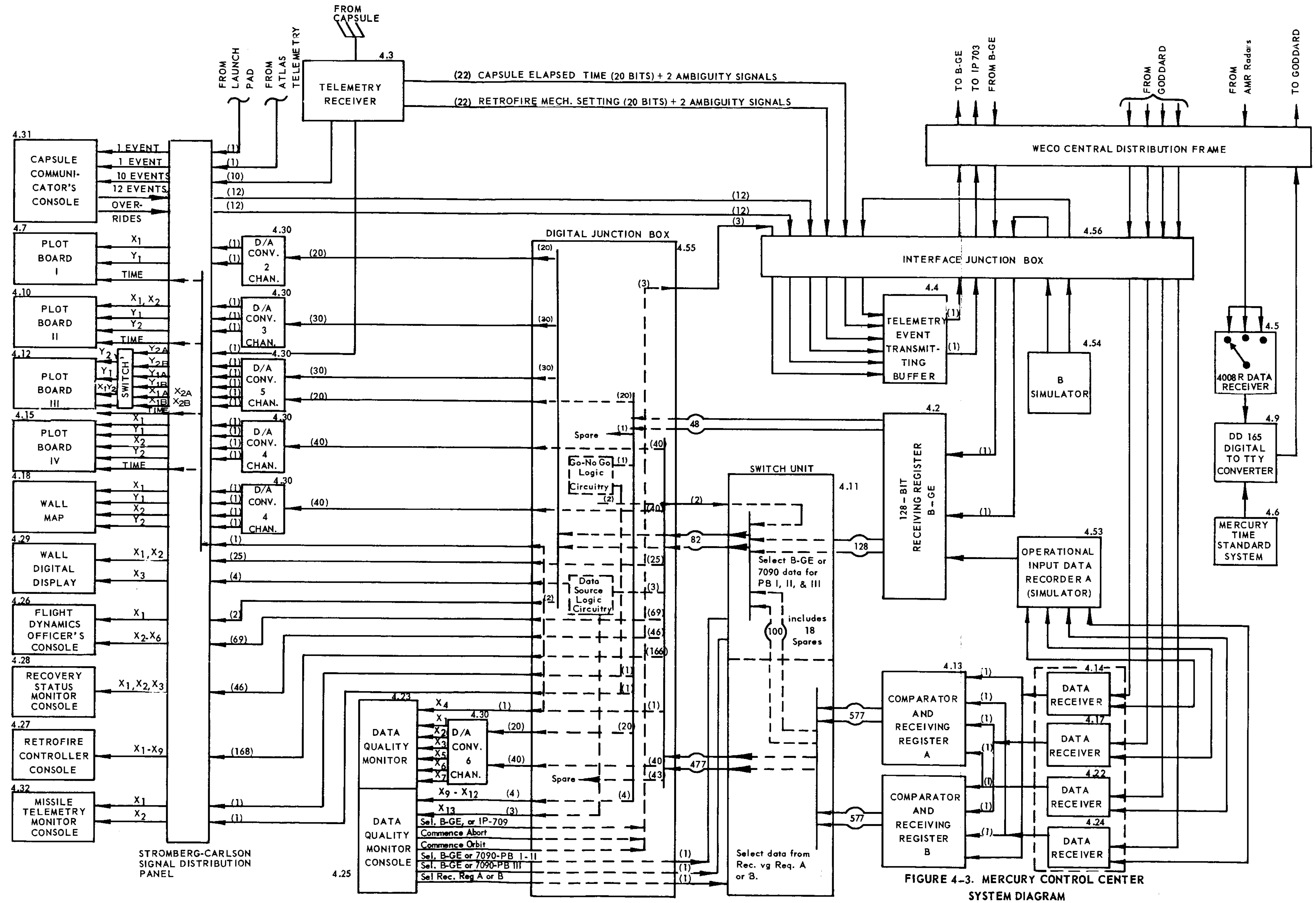


FIGURE 4-3. MERCURY CONTROL CENTER SYSTEM DIAGRAM

a. Data from external source (Burroughs-GE High-Speed Buffer and Dual Data Retransmitter)

b. All 1's

c. Alternate 1's and 0's

d. Alternate 0's and 1's

e. All 0's

f. Manual insertion of data

A red lamp is lighted whenever this switch is thrown to any of the test positions.

Neon lamps indicating the contents of the output storage device are used primarily during tests, when a test pattern should appear. However, they remain operational whenever the unit is in service.

1.1.3.3 Inputs

Incoming data is in the form of voice frequency tone bursts from the Burroughs-GE High-Speed Input Buffer and Dual Data Retransmitter. The carrier frequency is approximately 2 kc, modulated by 1/2-ms pulses for data. A 4-1/2-ms 2-kc tone burst followed by 1/2 ms of no tone is the end-of-word indication.

Incoming messages are received at approximately 1/2-second intervals. Each message consists of 128 bits of data at 1000 bits per second, followed by an end-of-word indication.

1.1.3.4 Outputs

The outputs of this unit are d-c levels on individual output lines. In addition, a hold signal is furnished 1 ms before the level changes on other output lines.

Some output lines are connected to the Missile Telemetry Monitor Console, the Data Quality Monitor, and the D/A converters associated with the Data Quality Monitor and Plot Board III.

The remaining output lines are connected to the Switch Unit for further distribution to the D/A converters associated with Plot Boards I, II, and III, and to the Flight Dynamics Officer's Console. Under control of the Data Selection Supervisor, the Switch Unit determines whether Burroughs-GE data or IBM 7090 data from Goddard will be sent to these D/A converters and the Flight Dynamics Officer's Console.

1.1.3.5 Effects of Malfunction

The data received directly from the Burroughs-GE Complex via the Model 78 Receiving Register may be partially or completely lost if this unit malfunctions. That portion of the data which would be displayed on Plot Boards I and II and on the Flight Dynamics Officer's Console is also available from the IBM 7090 Complex at Goddard, which could be used to provide the data in the event that Model 78 Receiving Register malfunctioned. The remainder of the data, displayed on Plot Board III during launch, the Data Quality Monitor Console, and the Missile Telemetry Monitor Console, is not directly available from another source and might be lost in the event of malfunction.

1.1.4 Switch Unit, Mercury Control Center

The Switch Unit (fig. 4-3) determines, under the control of the Data Selection Supervisor, whether data from the Burroughs-GE Complex or the IBM 7090 Complex at Goddard is fed into various displays at the Mercury Control Center, and whether data from Goddard is received via Receiving Register A or B. Specifically, this unit:

a. Accepts, in parallel, the outputs of the two Comparitor and Receiving Register Units and, under control of a switch on the Data Quality Monitor Console, selects one of these units to feed all digital displays: the D/A converters for the Wall Map Display, Plot Board IV, and the Data Quality Monitor and the relays which select Burroughs-GE or IBM 7090 data for Plot Boards I, II, and III.

b. Selects, under control of a switch on the Data Quality Monitor Console, Burroughs-GE or IBM 7090 data to feed the GO-NO-GO recommendation indicator on the Flight Dynamics Officer's Console, and the D/A converters for Plot Boards I and II.

c. Selects, under control of a separate switch on the Data Quality Monitor Console, Burroughs-GE or IBM 7090 data to feed the D/A converter for Plot Board III.

1.1.4.1 First-Level Selection Relays

1.1.4.1.1 Operation

The first-level selection relays determine whether data from Receiving Register A or B is utilized. Both receiving registers receive identical data from the IBM 7090 Complex at Goddard. Only one of these is in service; the other is spare. To switch the service and spare units, the Data Selection Supervisor operates a control on the Data Quality Monitor Console. This operates the first-level selection relays and thereby changes the selection of the units.

With no control signal, all the inputs from Receiving Register A are connected to output connectors or to second-level selection relays. With a control signal from the Data Quality Monitor Console, all the inputs from Receiving Register B are connected to output connectors or to second-level selection relays.

1.1.4.1.2 Inputs

There are 700 data conductors and spares from Receiving Register A and another 700 from Receiving Register B.

1.1.4.1.3 Outputs

The selected data conductors are connected as follows: 800, plus spares, to output connectors. These connect to all digital displays and the D/A converters for the Wall Map Display, Plot Board IV, and the Data Quality Monitor:

60, plus spares, to the first group of second-level selection relays.

40, plus spares, to the second group of second-level selection relays.

1.1.4.1.4 Spare Switching

In the event that any of the relays malfunction, erroneous data, or no data at all, may be displayed at a digital display console, Plot Board IV, the Wall Map Display, or the Data Quality Monitor. This malfunction may be circumvented as follows.

Spare input connectors can replace any of the Receiving Register A or B connectors. Similarly, spare output connectors are provided. Thus, relay malfunctions can be circumvented by moving two input cables and one output cable to corresponding spare locations. The relays for these spare positions operate at the same time as the relays that are normally used.

1.1.4.2 Second-Level Selection Relays, First Group

1.1.4.2.1 Operation

During the launch phase, Plot Boards I and II and the GO-NO-GO recommendation indicator on the Flight Dynamics Officer's Console display information which is available either from the IBM 7090 Complex or the Burroughs-GE Complex. The first group of second-level selection relays determine, under the control of the Data Quality Monitor Console, which source of data is used during this phase. The selection is made by the Data Selection Supervisor on the basis of which data appears, at the moment, to be most reliable.

During all other phases except launch, Plot Boards I and II and the GO-NO-GO recommendation indicator on the Flight Dynamics Officer's Console display information generated only by the IBM 7090 Complex at Goddard. The first group of second-level selection relays must therefore be in the IBM 7090 position during these phases.

With no control signal, the 60 conductors plus spares from the first-level selection relays (IBM 7090 data) are connected to the output connectors leading to the D/A converters associated with Plot Boards I and II and to the GO-NO-GO recommendations indicated on the Flight Dynamics Officer's Console. The relays may be in this position during the launch phase; they will be in this position during all other phases.

With a control signal from the Data Quality Monitor Console, the 60 conductors, plus spares, from the Burroughs-GE Receiving Register are connected to the output connectors leading to the D/A converters associated with Plot Boards I and II. This condition may exist only during the launch phase.

1.1.4.2.2 Inputs

There are 60 conductors, plus spares, from the first-level selection unit. There are also 60 conductors, plus spares, from the Burroughs-GE Receiving Register.

1.1.4.2.3 Outputs

The output of the first group of second-level selection relays are 60 output connectors, plus spares, leading into the D/A converters associated with Plot Boards I and II, and to the GO-NO-GO recommendation indicator on the Flight Dynamics Officer's Console.

1.1.4.2.4 Spare Switching

In the event that any of the relays in this group malfunction, erroneous data may be displayed on Plot Boards I and/or II. This malfunction may be circumvented as follows.

Spare input connectors can replace the inputs from Receiving Register A, Receiving Register B, and the Burroughs-GE Receiving Register. Similarly, spare output connectors are provided. Thus relay malfunctions can be circumvented by moving three input cables and one output cable to corresponding spare locations. The relays for these spare positions operate at the same time as the relays that are normally used.

It might be noted that, in the event of malfunction, both the first-level selection relays and the second-level selection relays are bypassed; it is possible, therefore, to circumvent the trouble without determining whether it occurs in the first- or second-level selection relays.

1.1.4.3 Second-Level Selection Relays, Second Group

1.1.4.3.1 Operation

During the launch phase, Plot Board III displays information generated by the Burroughs-GE computer, and telemetry information. During the orbit phase, this plot board displays information generated solely by the IBM 7090 Complex. The second group of second-level selection relays make the necessary connections to send data from the proper source to Plot Board III. With no control signal, the 40 conductors, plus spares, from the first-level selection relays (IBM 7090 data) are connected to the output connectors leading to the D/A converter associated with Plot Board III. This condition must exist during the orbit phase.

With a control signal from the Data Quality Monitor Console, the 40 conductors, plus spares, from the Burroughs-GE Receiving Register are connected to the output connectors leading to the D/A converter associated with Plot Board III. This condition must exist during the launch phase.

1.1.4.3.2 Inputs

There are 40 conductors, plus spares, from the first-level selection unit. There are also 40 conductors, plus spares, from the Burroughs-GE Receiving Register.

1.1.4.3.3 Outputs

Forty output connectors form the second group of second-level selection relays lead to the D/A converter associated with Plot Board III.

1.1.4.3.4 Spare Switching

In the event that any of the relays in this group malfunction, erroneous data may be displayed on Plot Board III. Such a malfunction may be circumvented by utilizing the spare relays and conductors.

1.1.4.4 Controls and Indicators

Two connectors or terminals are provided for each of three control signals (six terminals). Each terminal is connected to the Data Quality Monitor Console. The Switch Unit applies a voltage to one of each pair of terminals. A contact closure in the Data Quality Monitor Console applies this voltage to the other terminal, thereby accomplishing the following:

a. Select Receiving Register B: The first-level selection relays, under the control of the Data Quality Monitor Console, select data from Receiving Register A or B.

b. Select Burroughs-GE, Plot Boards I and II: The group 1 second-level selection relays, under the control of the Data Quality Monitor Console, select data from the IBM 7090 Complex or the Burroughs-GE Complex during the launch phase. During other phases, it selects only IBM 7090 data.

c. Select Burroughs-GE, Plot Board III: The group 2 second-level selection relays, under the control of the Data Quality Monitor Console, select Burroughs-GE data during the launch phase and IBM 7090 during the orbit phase.

Four indicators are associated with each of the three groups of relays (total, 12 indicators). In each group of 4, one of the two white indicators indicates which data source the control line has selected; one of the two green indicators confirms proper relay operation. Should the SELECT and CONFIRM indicators not agree, maintenance action will be necessary to correct the condition. (See tables 4-1 through 4-3.)

TABLE 4-1. INDICATORS FOR FIRST-LEVEL SELECTION

Indicator	Lights When
Register A selected (white)	No select-register-B control signal
Register B selected (white)	Select-register-B control signal
Register A confirmed (green)	Any of the first-level relays are not picked
Register B confirmed (green)	Any of the first-level relays are picked

Thus, both or neither of the two green indications indicate a malfunction

Register

A (white)	B (white)	Select
A (green)	B (green)	Confirm

TABLE 4–2. INDICATORS FOR SECOND-LEVEL SELECTION, FIRST GROUP

Indicator	Lights When
IBM 7090 selected for Plot Boards I and II	No select B-GE, Plot Boards I and II control signal. May be lit during launch phase; must be lit during all other phases.
B-GE selected for Plot Boards I and II (white)	Select B-GE, Plot Boards I and II control signal. May be lit only during launch phase.
IBM 7090 confirmed for Plot Boards I and II (green)	Any of the relays in this group are not picked. May be lit during the launch; must be lit during all other phases.
B-GE confirmed for Plot Boards I and II (green)	Any of the relays in this group are picked. May be lit only during launch phase.

Plot Boards I and II

IBM 7090 (white)	B-GE (white)	Select
IBM 7090 (green)	B-GE (green)	Confirm

TABLE 4–3. INDICATORS FOR SECOND-LEVEL SELECTION, SECOND GROUP

Indicator	Lights When
IBM 7090 selected, Plot Board III (white)	No select B-GE, Plot Board III control signal. Must be lit during orbit phase.
B-GE selected, Plot Board III (white)	Select B-GE, Plot Board III control signal. Must be lit during launch phase.
IBM 7090 confirmed, Plot Board III (green)	Any of the relays in this group are not picked. Must be lit during orbit phase.
B-GE confirmed, Plot Board III (green)	Any of the relays in this group are picked. Must be lit during launch phase.

Plot Board III

IBM (white)	B-GE (white)	Select
IBM (green)	B-GE (green)	Confirm

1.1.4.5 Output Status Signals

Two connectors or terminals are provided for each of six output signals (12 terminals). Each terminal is connected to the Data Quality Monitor Console.

For each pair of terminals, the Switch Unit provides relay contacts as described in table 4-4. The voltage to one of each pair of terminals is supplied by the Data Quality Monitor Console. A contact closure returns this voltage on the other terminal of the pair.

TABLE 4-4. OUTPUT STATUS SIGNALS

Output Status Signal	Furnished by Closure When
Register A confirm	Any of the first-level relays are not picked.
Register B confirm	Any of the first-level relays are picked.
IBM 7090 confirm Plot Boards I and II	Any of the first group of second-level data relays are not picked.
B-GE confirm Plot Boards I and II	Any of the first group of second-level data relays are picked.
IBM 7090 confirm Plot Board III	Any of the second group of second-level data ralays are not picked.
B-GE confirm Plot Board III	Any of the second group of second-level data relays are picked.

1.1.5 Model 77 D/A Converters, (MCC)

1.1.5.1 Function

Digital data concerning the flight of the Mercury capsule is processed by the Burroughs computer and the IBM 7090 Complex at Goddard, and transmitted to the Mercury Control Center for presentation on analog and digital displays. The D/A converters at the Mercury Control Center convert these 10-bit parallel d-c inputs into corresponding analog voltage outputs suitable for display on X-Y high-speed plotting boards. In addition, these units provide reference voltages to the display devices. (See fig. 4-3.)

1.1.5.2 Operation and Description

Each D/A converter unit consists of seven A/A channels, two power supplies, and a device for providing a reference analog voltage to the analog display system.

Each D/A channel converts a 10-bit digital d-c signal received over 10 parallel input lines into a single corresponding analog voltage. A hold-trigger signal is received about 1 ms before a new input signal arrives. This hold signal locks the output level until the input signal is received and all internal circuitry has stabilized, with no transients remaining. Each channel is capable of performing up to 50 D/A conversions per second.

Each unit has two power supplies. An automatic fail-safe provision causes instant switchover in the event any voltage goes off limits.

Several of these units, connected together in a system, provide plus and minus reference voltages to the X-Y plotters. Only one of the units in such a system supplies the reference voltages to all plotters. If this unit fails to supply the reference voltages, it is automatically disconnected from the reference supply lines, and another unit, selected on a priority basis, then controls and supplies the reference voltages.

1.1.5.3 Inputs

There are 10 parallel data input lines to each channel. The signals on these lines are d-c levels. A 0 is represented by 0± .5v; a 1 is represented by -17 ±3v.

A hold-trigger-input line, when pulsed externally at least 1 ms before entry of a new data on the data lines, causes all output analog voltages to hold until all internal circuitry has stabilized. A nonsignificant hold-trigger pulse has a value of 0±.5v; a significant hold-trigger pulse is represented by -17+3v.

A reference-disable-input line recognizes as a significant level any voltage in the range of +30 to +150v or -30 to -150v. This line is used in the control of the reference voltage supply system.

1.1.5.4 Outputs

One independent d-c voltage output is supplied for each channel of d-c conversion. The output voltage is -35v for a digital input of all 0's and +35v for an input of all 1's.

The system also supplies a ground reference line and +35v reference voltages as outputs. It also supplies a reference-disable-output line. This line indicates the presence of one of two conditions: either the unit is providing the proper reference voltages internally or there is a significant level on the reference-disable-input line.

1.1.5.5 Effect of Malfunction

Malfunctioning of the power supply of a D/A converter causes instant switchover to a second power supply in the unit. An alarm light indicates this condition so that necessary maintenance can be initiated on the defective power source.

Failure of the reference voltage source automatically causes the next D/A converter unit to become the source of supply for reference voltages. An alarm signals that the switch has taken place and that maintenance action is required on the unit that has failed.

Failure of a channel of a D/A converter affects only the individual plot associated with that channel.

1.1.6 Data Quality Monitor (MCC)

1.1.6.1 Function

Some of the data displayed at the Mercury Control Center during the launch phase may be produced by three alternate means: the Burroughs-GE computer, the IBM 7090 Complex at Goddard with B-GE data as its source of data, or the IBM 7090 Complex at Goddard with the IBM 709 Impact Predictor or the AN/FPS-16 radar system as its source of data. The Data Selection Supervisor determines which of these means will be used to generate the data displayed. The Data Quality Monitor assists him by enabling him to make a rapid visual comparison of two variable quantities as produced by each of the three sources. (See fig. 4-3.)

The variable quantities selected for comparison are V/V_R - V/V_R (nom) and $\gamma - \gamma$ (nom). These quantities displayed on the Data Quality Monitor in analog form on six channels of an 8-channel strip chart recorder and are updated every 1/2 second. In addition, timing marks are inserted on the other two channels of the strip chart.

1.1.6.2 Operation and Description

The Data Quality Monitor consists of an 8-channel strip chart recorder. During the launch phase, which is the only phase in which this equipment is used, six channels are used to record analog signals representing V/V_R - V/V_R (nom) and $\gamma - \gamma$ (nom) as generated by the Burroughs-GE computer, the IBM 7090 Complex at Goddard with Burroughs-GE data as its source of information, and the IBM 7090 Complex at Goddard with the IBM 709 Impact Predictor or AN/FPS-16 raw radar data as its source of information. The other channels record time marks.

Nine chart speeds are available, controlled by push-buttons located on the front panel: 0.25, 0.5, 1, 2.5, 5, 10, 25, 50, and 100 mm/sec. By manipulating these push-buttons, the operator can select a suitable and convenient speed.

A step type attenuator is provided for each channel, controlled by a switch on the front panel. This switch has the following steps, in volts/division: 0.1, 0.2, 0.5, 1, 2, 5, CALIBRATE, OFF. The inputs from the D/A converters range from -35v to +35v. These are passed through a 1.4:1 attenuator, so that the input signal then ranges from -25 to +25v. Since the full-scale deflection of a channel is 50 divisions, full-scale deflection of the chart recording occurs with a full-scale change in the analog input and a step attenuator switch setting of 1v per division.

The Data Quality Monitor has a 2v internal reference voltage for calibration. In addition, +2v is available to energize the timing marker styli via remote switch closures.

1.1.6.3 Inputs

The Data Quality Monitor has eight input channels. Six of these channels accept an analog voltage signal changing at a 1/2-second rate. These analog signals range from -35v to +35v.

One channel accepts timing signals, which consist of contact closures of 50-ms duration. One closure occurs every second as a second mark. Every 10 seconds, additional closures at a 100-ms contact closure rate indicate in serial decimal form the tens of hours, hours, tens of minutes, minutes, and tens of seconds.

1.1.6.4 Outputs

Data is permanently recorded on the strip chart in analog form. Each stylus is capable of a full-scale deflection of 1-9/16 inches (4 cm). This corresponds to 50 divisions on the paper. The channels do not overlap.

Timing markers are displayed as deflections along the right-hand edge of their channels. An output of +2v is returned through the remote contact closures of the timing signals.

1.1.6.5 Effects of Malfunction

The Data Quality Monitor helps the Data Selection Supervisor determine the most reliable source of data for display at the Mercury Control Center. Malfunctioning of the entire Data Quality Monitor will therefore make it more difficult for the Data Selection Supervisor to determine the most reliable source, but will not have a direct effect on the operational data displayed on other consoles.

1.1.7 Data Quality Monitor Console (MCC)

1.1.7.1 Function

The Data Quality Monitor Console is an attachment to the Data Quality Monitor which makes possible specific control and monitor functions. (See fig. 4-3.)

It enables the Data Selection Supervisor to monitor the data flow system as follows. Four data quality signals are displayed, which indicate the reliability of the data generated by the Burroughs-GE Complex. In addition, four status signals are displayed. These indicate the sources of the data currently being transmitted to the other displays throughout the Mercury Control Center. The Data Selection Supervisor also refers to the Data Quality Monitor (par. 1.1.6).

Five control signals are generated at the Data Quality Monitor Console. They determine whether the IBM 7090 Complex at Goddard uses Burroughs-GE data or IBM 709 Impact Predictor data (or AN/FPS-16 raw radar data) as its source of data, whether Burroughs-GE or IBM 7090 data is fed to Plot Boards I and II whether Burroughs-GE or IBM 7090 data is fed to Plot Board III, and whether IBM 7090 data is received via Receiving Register A or B. The signals indicate to the IBM 7090 Complex at Goddard what phase the mission is currently in.

1.1.7.2 Operation and Description

The Data Quality Monitor Console is an attachment to the Data Quality Monitor. Its physical appearance is shown in figure 4-7.

A 2-position switch labeled IBM 7090 determines whether Burroughs-GE or IP 7090 data is processed by the IBM 7090 at Goddard. This decision is transmitted to Goddard by means of telemetry signals. Each switch position energizes an associated white indicator. Directly below each white indicator is a green indicator which confirms that the computer is now utilizing the selected data source for processing.

A 2-position switch labled PLOT BOARD I, II controls the first group of second-level selection relays of the Switch Unit to select Burroughs-GE or IBM 7090 data for display on Plot Boards I and II, and the GO-NO-GO recommendation on the Flight Dynamics Officer's Console. During the launch phase, this switch should select Burroughs-GE data; during all other phases, the switch must select IBM 7090 data for display since the desired information is not available from the Burroughs-GE Complex. Each switch position energizes an associated white indicator. Directly below each white indicator is a green indicator which confirms that the Switch Unit has actually selected the desired data source.

A 2-position switch labled PLOT BOARD III controls the second group of second-level selection relays of the Switch Unit to select Burroughs-GE or IBM 7090 data for display on Plot Board III. During the launch phase, this switch must be set to select Burroughs-GE data since the information displayed is not available from Goddard; during the orbit phase, this switch must select IBM 7090 data. Each switch position energizes an associated white indicator. Directly below each white indicator is a green indicator which confirms that the Switch Unit relays have actually selected the desired data source.

The 2-position switch labled REGISTER controls the first-level selection relays of the Switch Unit to determine whether data from the Goddard Complex is received via Receiving Register A or B. This switch may therefore be used to switch receiving registers in the event that one of them malfunctions. Each switch position energizes an associated white indicator. Directly below each white indicator is a green indicator which confirms that the Switch Unit relays have actually selected data from the desired receiving register.

A 3-position switch labeled FLIGHT PHASE is used to indicate to the Goddard computer via telemetry signals the phase that the mission is in. During the launch phase, this switch must be in the normal position. The left-hand position is used during the abort phase, and the right-hand position is used during the orbit phase. Each of these last two switch positions energizes an associated white indicator. Directly below each of these white indicators is a spare. An indicator assembly labeled B-GE DATA QUALITY contains a group of four indicators. Three of these indicators contain red lenses and are labeled $\delta 1$, $\delta 2$, and $\delta 3$, respectively. The fourth indicator, containing an amber lens, is labeled δn. These flags have the following significance:

$\delta 1$ - A signal indicates that the computer is integrating rates of change to obtain range, azimuth, and elevation.

$\delta 2$ - A signal indicates that the computer is differentiating range, azimuth, and elevation to obtain rates of change.

$\delta 3$ - A signal indicates that the computer is differentiating track data to obtain lateral rates only.

δn - A signal indicates that the computer is not receiving sufficient data to generate guidance commands.

An additional indicator, containing a green lens and labeled POWER ON, indicates when power is present in the unit and turns on simultaneously with power on to the Data Quality Monitor.

1.1.7.3 Inputs

The inputs to this unit consist of status signals from the Switch Unit and data quality signals from the Simplex Receiving Register.

Four status signals are received as follows:

a. Data source for IBM 7090 computer: Indicates whether B-GE or IP 709 (or AN/FPS-16) data are being utilized.

b. Source of data for Plot Boards I and II: Two separate lines are provided from the Switch Unit. When one is energized, B-GE data are being displayed. When the other is energized, data displayed on Plot Boards I and II are from the Goddard Complex.

c. Source of data for Plot Board III: Two separate lines are provided from the Switch Unit. When one is energized, B-GE data are being displayed. When the other is energized, data displayed on Plot Board III are from the Goddard Complex.

d. Receiving register selection: Two separate lines are provided from the Switch Unit. When one is energized, data from Receiving Register A are being displayed. When the other is energized, data displayed are received via Receiving Register B.

The four data quality signals are received over separate lines. A significant level indicates that the data represented by the flag are valid. A nonsignificant level indicates that the data associated with the flag are not valid.

1.1.7.4 Outputs

The Data Quality Monitor Console generates outputs which indicate the selections that have been made by switch operation, as follows:

a. IBM 7090 switch: Output consists of a contact closure to return a voltage to the Telemetry Event Transmitting Buffer when B-GE data are selected as the input to the 7090 computer. Open contacts result in the absence of signal on the return line when IP 709 or AN/FPS-16 data are selected as input to the 7090.

b. Plot Boards I and II switch: Output consists of a contact closure to return a voltage to the first group of second-level selection relays of the Switch Unit when B-GE data are selected for display. Open contacts result in the absence of a control voltage when IBM 7090 data are selected.

c. Plot Board III switch: Output consists of a contact closure to return a voltage to the second group of second-level selection relays of the Switch Unit when B-GE data are selected for display. Open contacts result in the absence of a control voltage when IBM 7090 data are selected.

d. Register switch: Output consists of a contact closure to return a voltage to first-level relays of the Switch Unit when Register B is selected as the data source for IBM 7090 data. Open contacts result in the absence of a control voltage when Register A is selected.

e. FLIGHT PHASE switch: Output consists of a contact closure on either of two output lines to indicate to the IBM 7090 computer via Telemetry Event Transmitting Buffer that it should use the orbit or abort programs. Absence of signals on both output lines indicates that the flight is still in the launch phase, and that the launch program should be used.

1.1.7.5 Effects of Malfunction

The indicators on the Data Quality Monitor Console give positive visual indications that all data selection commands originated at the console have been effected. Any malfunctioning of the data selection system would therefore be rapidly determined, and corrective action initiated.

1.1.8 Telemetry Event Transmitting Buffer

1.1.8.1 Function

The Telemetry Event Transmitting Buffer (fig. 4-3) receives digital data in parallel format from the Capsule Communicator's Console, the Telemetry Receiver, and the Data Quality Monitor Console. These data, which describe discrete events, are buffered and then transmitted continuously over two separate high-speed data lines to the high-speed input buffer and dual data retransmitters associated with the B-GE and IP 709 Complexes.

1.1.8.2 Operation and Description

The Telemetry Event Transmitting Buffer accepts digital data in parallel format and converts these signals into serial format for transmission. A 72-bit serial output message is generated every 74 ms.

All input signals are in digital d-c format, except for two ambiguity signals which are received as analog voltages from the Telemetry Receiver. These ambiguity signals are associated with the Capsule Elapsed Time and Retrofire Mechanism setting and indicate whether the telemetry signal describing these quantities is too weak for accurate resolution. Validity bits are also associated with these time quantities and have a significant value when time data enters the Telemetry Receiver while the time output is being sensed. If either the validity bit or the ambiguity signal (or both) associated with the Capsule Elapsed Time has a significant value, the Telemetry Event Transmitting Buffer transmits a bit to indicate the time quantity is not valid. In connection with the Retrofire Mechanism Setting, a 1 is generated in bit position 42.

The Telemetry Event Transmitting Buffer also generates a parity bit. This bit is a 1 when there are an even number of 1's in the first 71 bits, and a 0 when there are an odd number of 1's in the first 71 bits.

A test feature is included to provide a rapid check on the operation. The test involves loading the buffer with 1's and monitoring the output. If an error occurs, an error lamp is turned on.

The input signals from the Capsule Communicator's Console consist of the following 12 telemetry event signals and 12 override signals associated with these events:

a. Liftoff

b. Staging

c. Escape tower released

d. Tower escape rockets fired

e. Capsule released from sustainer

f. One of three posigrades fired

g. Two of three posigrades fired

h. Three of three posigrades fired

i. Abort sequence initiated

j. Retro 1 fired

k. Retro 1 and 2 fired

l. Retro 1, 2, and 3 fired

The signals from the Telemetry Receiver consist of two 20-bit compressed BCD time quantities indicating Capsule Elapsed Time and Retrofire Mechanism Setting. One validity bit is associated with each of these time quantities and has a significant value when the time quantity changes while it is being sensed. In addition, an ambiguity signal, in the form of an analog voltage, is associated with each time quantity, and indicates whether telemetry signal describing these quantities is too weak for accurate resolution.

The input signals from the Data Quality Monitor Console consist of one bit to indicate data source selection and two bits to indicate flight phase. In each case, a significant value (binary 1) indicates that the discrete event has occurred. These significant values are indicated by contact closures.

1.1.8.3 Outputs

Each duplexed transmitter of this unit is capable of driving one or two high-speed data lines. The output signals are modulated tone bursts at 1000 bits per second. The carrier is 2-kc, modulated by 1/2-ms pulses. An output message consists of a start-of-message indication of 1-1/2 ms of carrier tone, followed by 1/2 ms of no tone, and then 72 bits of data. Total transmission time for a complete message is 74 ms, and messages are sent continuously.

1.1.8.4 Malfunctions

There are two power supplies in this unit, either of which is capable of supplying the entire unit. A voltmeter is available to read their output. Switching in the event of malfunction is manual.

The remainder of the circuitry is also duplexed. In normal operation, each unit feeds one of the two output lines. In the event of malfunction, either unit may be switched manually to feed both output lines.

Malfunctioning of the Telemetry Event Transmitting Buffer results in erroneous telemetry event indications being sent to Goddard and displayed at the Mercury Control Center.

1.1.9 Model 75 Data Receivers

1.1.9.1 Function

Digital data concerning the flight of the Mercury capsule are processed by the IBM 7090 Complex at Goddard for display at various analog and digital displays in the Mercury Control Center. These data are converted into voice frequency signals suitable for transmission over high-speed data lines and transmitted over four such lines to the Mercury Control Center. The information on the four lines is identical except that a different delay of up to 16 ms is introduced into each line by the data transmitters at Goddard.

Each of the four Milgo Model 75 Data Receivers at the Mercury Control Center is connected to one of these lines. (See fig. 4-3.) The receivers convert the voice frequency, AM signals from the high-speed data lines into binary d-c levels, suitable for the operation of digital equipment and displays. The output of three of the receivers is connected to the comparator and receiving register units; the fourth unit may be substituted in case of malfunction of any one of the other three.

Specifically, these data receivers:

a. Convert voice frequency tone bursts into binary d-c levels.

b. Recognize discrete start-of-message and end-of-message signals, and convert these into d-c levels on separate output lines.

c. Delay their output up to 16 ms, so that the same bit is emitted by each simultaneously, despite the fact that inputs may vary from each other by as much as 16 ms.

d. Provide a 1-kc pulse, derived from incoming data, to control shift registers in synchronization with the arrival of data bits.

1.1.9.2 Operation and Description

During the prelaunch checkout, the data receivers should be adjusted so that all four emit the same bit of information simultaneously. This is accomplished by adjusting switches to introduce a different delay in each receiver so that all paths from the IBM 7090 Complex at Goddard to the Mercury Control Center have the same total delay; that is, the delay introduced by the transmitter, plus the delay of the transmission line, plus the delay introduced by the receiver will be the same for all four paths. One 17-position switch on each data receiver introduces a delay of from 0 to 16 ms, at intervals of 1 ms. This delay is effected by shifting the data through a 16-position register at a rate of 1000 shifts per second. For each position that the data is shifted through the register, a delay of 1 ms is introduced.

Neon lamps indicate the data stored in the shift register. A test switch can be used to manually insert information in the register. A SHIFT ONE and a SHIFT ZERO pushbutton allow selection of any desired information pattern.

1.1.9.3 Inputs

Each data receiver is connected to a high-speed data line transmitting signals from the IBM 7090 Complex at Goddard. These signals are in the form of a 2-kc carrier, modulated by 1/2-ms pulses. Incoming data is in serial form at a rate of 1000 bits per second.

Discrete voice frequency signals indicate the start and end of a message. A start-of-message indicator consists of 1-1/2 ms of carrier tone, followed by 1/2 ms of no tone; the end-of-word indicator consists of 4-1/2 ms of carrier frequency tone, followed by 1/2 ms of no tone.

A complete frame consists of a start-of-message indicator, 408 bits of information, and an end-of-message indicator, for a total length of 415 ms. An odd frame and an even frame are sent alternately every 1/2 second during the launch phase and every second during the abort phase; an odd frame and an even frame immediately following are sent every 12 and 6 seconds during the orbit and re-entry phases respectively.

1.1.9.4 Outputs

The output is in serial form at a rate of 1000 bits per second, or 1 ms per bit. A separate output line carries timing pulses at a 1000-pulse-per-second rate. Additional output lines are pulsed when a start-of-message or end-of-message indication is received.

1.1.9.5 Malfunctioning of Data Transmission System

Malfunctioning of the data transmitter, high-speed line, or data receiver on any path between Goddard and the Mercury Control Center will cause erroneous data to be emitted by the receiver at the Mercury Control Center. The outputs of three of the data receivers are connected to a comparator. This unit compares the three bits received and accepts as valid the two (or three) that agree. Only this validated bit is sent for display to the consoles throughout the Mercury Control Center. Erroneous bits emitted by one malfunctioning data receiver will therefore not be transmitted to the display consoles. Malfunctioning of any one path between Goddard and the Mercury Control Center will not affect the information displayed at the Mercury Control Center.

1.1.10 Comparator and Receiving Register Units

1.1.10.1 Function

The Comparator and Receiving Register Unit accepts identical data in serial form, at a rate of 1000 bits per second, from the data receivers. (See fig. 4-3.) These data originate at the IBM 7090 Complex at Goddard for display at various consoles throughout the Mercury Control Center. The comparator logically compares the bits from the three receivers and accepts as valid any two that agree. In this way, an erroneous bit occurring between Goddard and the Mercury Control Center is rejected. The validated bits are then converted from serial to parallel form, suitable for distribution via the switching unit to the proper displays. The comparator also compares, bit by bit, the output of each of the four data receivers with the validated bit, and pulses a meter associated with the receiver each time a discrepancy is noted. In this way, the errors received from each of the four data receivers are indicated. An alarm is also provided whenever the error rate of any receiver exceeds a specified level. Two Comparator and Receiving Register Units identified as Receiver Registers A and B are duplexed to increase reliability.

Specifically, these units:

a. Select, under control of a switch, three data receivers (out of four) as inputs to the two-out-of-three comparison check.

b. Compare, bit by bit, the input data from three data receivers and accept as valid any two that agree.

c. Provide an indication of the number of erroneous bits emitted by each of the four data receivers.

d. Light an alarm lamp whenever the error rate of any receiver exceeds a specified level.

e. Convert serial input to parallel output.

f. Provide separate parallel outputs for alternate frames of bits 86 to 256. These bits contain information for digital displays; some of the information is contained in even frames, some in odd frames.

1.1.10.2 Operation and Description

These units consist of a comparator to validate the bits, a 408-bit shift register to convert data from serial to parallel format, and a 579-bit storage register to store the output.

The output of each data receiver is compared, bit by bit, with the validated bits in the comparator. When a bit emitted by one of the receivers does not agree with the validated bit, a meter associated with that receiver is pulsed. Reading the four meters will therefore give an indication of the error rate of each data receiver.

A 4-position switch on the comparator determines which three of the four data receivers are being utilized as inputs for the two-out-of-three comparison check. This switch should be set so that the data receiver with the highest error rate (as determined in the preceding paragraph) is not used as an input. This data receiver, and the data transmitter and high-speed data line associated with it, can then be released for maintenance.

A red alarm lamp is arranged to light when the error rate of any of the error meters rises above a predetermined level. This lamp indicates when data from one or more data receivers has an unacceptably high error rate. Inspection will then enable corrective action to be taken, as outlined in the preceding paragraphs.

A 4-position switch enables the operator to manually insert test data into the shift register. This switch enables single-cycling 24 information bits for each register section in the following formats:

a. All 1's

b. Alternate 1's and 0's

c. Complement of b.

d. All 0's

A red lamp is lighted whenever this switch is thrown to insert test information into the shift register.

Neon lamps are used to indicate the information stored in the 579-bit receiving register. These lamps are used primarily during tests, when the register contains a test pattern; however, they remain operational at all times.

A red alarm lamp is lighted whenever the internal 12v supply of the Comparator and Receiving Register Unit fails.

1.1.10.3 Inputs

These units accept digital data in serial format at 1000 bits per second from four data receivers. (Only three of the inputs are fed into the two-out-of-three comparison check.) A complete frame contains 408 data bits. A 0 is represented by a voltage between +0.5v and -0.8v. A 1 is represented by a voltage between -15v and -20v.

The data receivers supply copy pulses at a rate of 1000 pulses per second over four separate input lines for internal control of data and end-of-message signals over four separate input lines for additional internal control of data.

1.1.10.4 Outputs

The output lines of each Comparator and Receiving Register Unit are connected with the Switch Unit. The data are in binary d-c form, and the output consists of 579 bits read out in parallel.

A separate hold-trigger output signal is transmitted not less than 1 ms before new data is entered on the output data lines. This control signal holds the output of the D/A converters until new data is received and internal circuitry is stabilized.

1.1.10.5 Malfunction

1.1.10.5.1 Effects of Malfunction

Malfunctioning of a Comparator and Receiving Register Unit may cause erroneous data to be distributed to one or more display consoles throughout the Mercury Control Center. Complete failure of such a unit would cause it to emit all 0's (that is, 0 voltage) on the output lines. Partial failure might affect only a portion of the output. Since two Comparator and Receiving Register Units are duplexed to provide increased reliability, a malfunctioning unit can be switched by the Data Quality Monitor to the spare condition and the properly functioning unit placed in service.

1.1.10.5.2 Operational Indications of Malfunction

Malfunctioning of a Comparator and Receiving Register Unit <u>may</u> be indicated by obviously incorrect data being displayed at one or more consoles displaying data from the IBM 7090 Complex at Goddard. At the Data Quality Monitor strip chart, for example, such an indication might be that the values displayed for V/V_r and/or $\gamma - \gamma$ nom as received from the IBM 7090 Complex do not agree with the display of the same quantities as generated by the B-GE Complex.

It should be emphasized that not every malfunction of these units will result in obviously erroneous displays; conversely, not all erroneous displays will be the result of faulty Comparator and Receiving Register Units.

A red alarm lamp on each unit lights when the internal 12v supply fails. When this alarm light is lit, the unit with which it is associated has failed and should be removed from service immediately by operation of the Switch Unit from the Data Quality Monitor Console.

A malfunction is indicated if there is a jump, change, or discontinuity in any digital or analog display of Goddard data when the Switch Unit is operated and changes the receiving register selected for service. If such a jump or discontinuity occurs, further testing (as outlined in the following paragraph) may be necessary to determine which unit is malfunctioning.

Malfunctioning of the Comparator and Receiving Register Units can be determined from analysis of the 579 neon lamps, which indicate the contents of the storage register on each unit. During operations, a malfunction is indicated if the lamps on the two units do not agree. Such a comparison is difficult to make unless the trouble is fairly obvious, such as an entire group of lamps incorrectly remaining lighted or dark. However, test patterns can be inserted in the register units, and a rapid visual check for the desired pattern will indicate whether the unit being tested is malfunctioning. During operations, test data should never be inserted into a receiver while it is in service; however, test data may be inserted into the spare unit.

1.1.11 Capsule Communicator's Console

The Capsule Communicator's Console (fig. 4-3) has various functions which contribute to the Mercury mission. The following description, however, covers only those aspects of the unit that directly affect the Mercury Launch Subsystem.

1.1.11.1 Function

Telemetry signals describing 12 discrete events are received from the capsule via the telemetry receiver, from the launch pad, and from the vehicle telemetry system. The Capsule Communicator verifies the accuracy of the telemetry information, and the Capsule Communicator's Console enables him to manually override the incoming telemetry data if he believes it in error.

1.1.11.2 Operation and Description

Incoming telemetry data from the capsule, the launch pad, and the vehicle telemetry system indicates by means of a contact closure (binary 1) whether each of 12 discrete events has occurred. A lamp indicator, a 3-position toggle switch, and two output lines (a telemetry event signal and an override signal) are associated with each of the following events:

a. Liftoff

b. Staging

c. Escape tower released

d. Tower escape rockets fired

e. Capsule released from sustainer

f. One of three posigrades fired

g. Two of three posigrades fired

h. Three of three posigrades fired

i. Abort sequence initiated

j. Retro 1 fired

k. Retro 1 and 2 fired

l. Retro 1, 2, and 3 fired

When the incoming data indicates by the absence of a contact closure that the event has not occurred, the Capsule Communicator may accept the telemetry data as valid and leave the toggle switch in the center (normal) position, or he may decide that the event has not occurred and throw the toggle switch to the bottom (no event) condition. In either case, the event output will be 0 (no event), the override output will be 0 (no override), and the lamp indicator will be unlit (no event). If the Capsule Communicator decides that the event has occurred, he throws the toggle switch to the top (event) position. This changes the event output signal to 1 (override decision) and lights the lamp indicator to show that the event has occurred; the override bit will be 1. Should the incoming telemetry signal later change to indicate that the event has occurred, the override output signal will change to 0, indicating agreement between telemetry signals and the Capsule Communicator's decision.

When the incoming telemetry data indicates by contact closure that the event has occurred, the Capsule Communicator again may accept the telemetry data as valid and leave the switch in the center (normal) position, or he may decide that the event has occurred and throw the switch to the top (event) position. In either case, the event output will be 1 (event occurred), the override output signal will be 0 (no override), and the lamp indicator will be lit (event occurred). If the Capsule Communicator decides that the event has not occurred, he throws his switch to the bottom (no event) position. This changes the event output to 0 (no event) and the override output to 1 (override), and the lamp indicator will be unlit (no event). Should the Capsule Communicator later determine that the event has occurred, he must then change the switch position to either normal or event. The telemetry event output will then change to 1 (event) and the override output to 0 (no override), and the lamp will be lit (event occurred).

It might be noted that the Capsule Communicator should not confirm the fact that an event has not yet occurred when the incoming telemetry data also indicates the event has not yet occurred. Should the event occur later and be indicated by the incoming telemetry data, the output from the console would still indicate that the event has not taken place until the Capsule Communicator changes the switch position to either NORMAL or EVENT.

Table 4-5 is a summary of the controls, indicators, and outputs of the console.

TABLE 4-5. INCOMING TELEMETRY DATA

Toggle Switch Position	No Event (Binary 0)			Event (Binary 1)		
	Event Output	Override Output	Lamp	Event Output	Override Output	Lamp
EVENT	1	1	Lit	1	0	Lit
NORMAL	0	0	Unlit	1	0	Lit
NO EVENT	0	0	Unlit	0	1	Unlit

1.1.11.3 Outputs

The output signals transmitted to the Telemetry Event Transmitting Buffer consist of 12 telemetry event signals and an override signal associated with each. For telemetry event outputs, a significant value (binary 1) indicates that the event has occurred. A significant value on an override output line indicates that the Capsule Communicator has overridden the incoming telemetry data.

1.2 EQUIPMENT AT GODDARD SPACE FLIGHT CENTER

1.2.1 Data Communications Channel

1.2.1.1 Function

The Data Communications Channel replaces data channel F of the IBM 7090 computer and allows transmission of data between the computer and external data devices. (See fig. 4-4.)

1.2.1.2 Operation and Description

The Data Communications Channel consists of 32 subchannels, 28 of which have a functional designation. Sixteen of the subchannels are assigned to accept radar and telemetry data from the sites via TTY devices at the rate of 60 wpm. Two subchannels accept high-speed (1000 bits/sec.) radar and telemetry data from the B-GE and IP 709 high-speed buffers at Cape Canaveral via Milgo Model 72 Data Receivers. There is one paper tape input subchannel for manually inserted data not used on a real-time basis. In addition, three subchannels are allocated for external and internal timing co-ordination.

Two TTY output subchannels transfer data to a TTY distributing device, which in turn can select any of eight terminal devices. The TTY output information consists of acquisition data which is transmitted to the tracking stations.

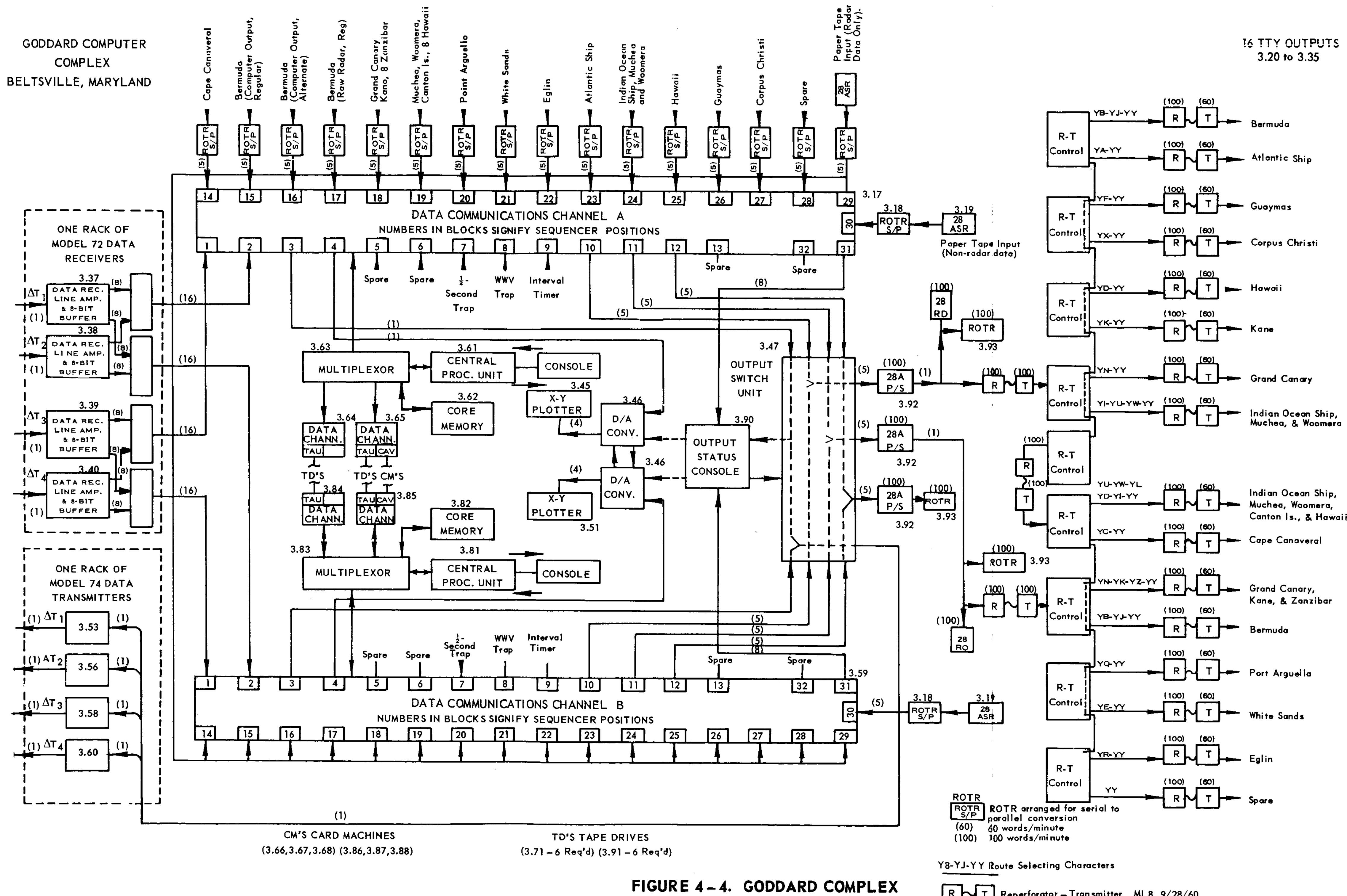


FIGURE 4-4. GODDARD COMPLEX SYSTEM DIAGRAM

A third TTY output is spare. Two high-speed output subchannels are provided: one transmits data to the Mercury Control Center via four Milgo Model 74 Data Transmitters; the other feeds a D/A converter, which in turn drives a Goddard plot board. A sense output subchannel operates the lamp displays on the Output Status Console.

Each subchannel has its own 14-bit address register composed of a fixed and a variable portion. The fixed portion controls the size and location of the core storage block related to that particular subchannel. Incoming data enters the first location of the block and fills successive words until the block is filled. The variable portion steps up each time a word enters the core until the data length of the block is attained. The variable portion is then reset to all 0's.

A sequencer within the Data Communications Channel inspects each address register, and data available for transfer to core storage is transferred by a multiplexor when the sequencer is positioned at the associated subchannel. The sequencer inspects the subchannels in the order indicated in figure 3-6. However, at each point in its sweep, the sequencer first tests the high-speed lines and, if they are ready to transmit, gives them priority over other subchannels.

1.2.1.3 Inputs

The 16 TTY input subchannels and the paper tape input subchannel accept data in 5-bit parallel characters at the rate of six characters per second. Upon placement of six characters in six consecutive storage locations in the address register, a program interrupt is effected.

Each high-speed input subchannel accepts the same data from two parallel synchronized lines at the rate of 1000 bits per second and in 8-bit bytes. After 24, 8-bit bytes have been stored, the program is interrupted.

Three subchannels are provided for timing co-ordination. One input is a voltage level change each minute. A second is a 60-cycle, 10v sine wave. Both inputs are accurate to 1 ms. The third is an interval timer which is set by entering the desired interval in a cell and activating the timer's subchannel.

1.2.1.4 Outputs

The TTY output is in the same form as TTY input. However, the transmission rate is 10 characters per second.

The high-speed output blocks are 32 words long, and 8-bit words are transmitted at the rate of 1000 bits per second. However, a trap will occur before a block is 32 words long if a 1 appears in the sign position of a word.

One sense output subchannel furnishes status information to the Output Status Console in 8-bit parallel form.

1.2.1.5 Effects of Malfunction

The 7090 Complex is duplexed so that in the event of malfunction of one computer and/or its associated units, the other computer and its units can be selected to furnish output data. This selection is made by the output switch under control of the Output Status Console.

1.2.2 Output Status Console

1.2.2.1 Function

The Output Status Console (fig. 4-4) provides each computer with a set of indicator lights which indicate the quality of each computer's output. With the plot boards (par. 1.19), these indicators allow the console operator to select the computer that will provide data for the Mercury Control Center and the range stations.

1.2.2.2 Operation and Description

The indicator and controls provided on the Output Status Console are shown in figure 4-9. Eight indicator lights for each computer provide information on computer functioning.

A 2-position switch controls the selection of one of the 7090 computers by the Output Switch Unit. The 2-position switch has four indicators associated with it. Two of these indicate the selection made and two, under the control of the output switch, confirm this selection.

A second 2-position switch provides for crossing of computer to D/A. In one position, data processed by Computer A is fed via the D/A converters to Plot Board A and Computer B data to Plot Board B. In the opposite position, Computer A drives Plot Board B and Computer B drives Plot Board A. Selection and confirmation of the selection are indicated by lamps.

1.2.2.3 Inputs

The input to the Output Status Console is in 8-bit parallel form from the sense output subchannel of each Date Communications Channel. Seven bits, when a 1, light indicators. The eighth, when a 1, lights an indicator and activates an audible alarm.

1.2.2.4 Effects of Malfunction

Malfunction of the Output Status Console might result in failure to switch from a faulty computer. However, the Goddard plot board operator and the Data Selection Supervisor at Cape Canaveral are also in a position to detect errors and are in voice contact with the console operator.

1.2.3 Computer-Related Teletypewriter Communications

1.2.3.1 Function

This portion of the teletypewriter communications system is duplexed and enables the automatic reception and transmission of radar and telemetry data needed on a real-time basis by each of the IBM 7090's at the GSFC. In addition, provision is made for the manual insertion of teletypewriter data not needed on a real-time basis. (See par. 3.6 and fig. 4-4.)

1.2.3.2 Operation and Description

Radar, telemetry, and IBM 709 (Bermuda) data is transmitted to Goddard over telephone lines in standard TTY messages consisting of 5-bit serial characters at the rate of 60 wpm. Mercury sites involved in the transmission of these data are:

Cape Canaveral	Point Arguello
Bermuda	White Sands
Grand Canary	Eglin
Kano	Atlantic Ship
Zanzibar	Indian Ocean Ship
Muchea	Guaymas
Woomera	Corpus Christi
Canton	Hawaii

The TTY data are received at Goddard by ROTR's which sense the incoming messages and convert them into 5-bit parallel characters for use by the Data Communications Channel. Sixteen input subchannels of each Data Communications Channel are capable of accepting this parallel data at the rate of five char/sec. Figure 3-6 shows the site TTY input-to-DCC configurations, and paragraph 2.4, Chapter 2, discusses the information content of this TTY data.

The input data is processed under 7090 program control and transmitted at the rate of 100 wpm by two subchannels of each Data Communications Channel, via the Output Switch, to teletypewriter equipment. Data is sent in parallel from each output subchannel in the form of 5-bit characters to a 28A distributor. The 28A converts this data into 5-bit serial form and adds start-of-message and end-of-message indicators for TTY system control. Each 28A distributes the converted data to one of eight terminal reperforator transmitters by inspection (under TTY system control) of the computer-prepared address formats. Transmission to the sites is at the rate of 60 wpm. The 28A also distributes its output to a 28RO and a 28 ROTR, which provide a record copy and typed punched tape, respectively.

1.2.4 Model 72 Data Receivers

1.2.4.1 Function

Each of the four data receivers (fig. 4-4) accepts high-speed serial data transmitted by the MCC in the form of modulated tone bursts over standard telephone lines and converts this data into parallel digital form. The receivers then transfer the digital data to the Data Communications Channels.

1.2.4.2 Operation and Description

The four Model 72 Data Receivers located at the GSFC operate in pairs. One pair of receivers accepts data over duplexed data lines from the Burroughs-GE Complex; the other pair, from the IP 709 Complex. Each receiver has an 8-bit input buffer shift register. Associated with each pair of receivers are two 16-bit output buffer registers, each composed of two 8-bit sections. One 8-bit section is loaded from one input register of its pair, and the remaining section from the other input register. Therefore, identical data is stored in both output registers for simultaneous parallel readout to each Data Communications Channel.

1.2.4.3 Inputs

The inputs to the receivers are in the form of tone bursts of 2-kc, equalized for a 1-kc data bit rate. The bursts range in duration from 1/2 ms to 2-1/2 ms for start-of word and 4-1/2 ms for end-of-word indications. Each data input is capable of 0- to 16-ms delay in 1-ms increments.

1.2.4.4 Outputs

Each receiver presents eight parallel data lines to each Data Communications Channel. The lines are arranged in two sets of 16 for each receiver pair. Data available on these lines is indicated by a level. Binary 1's are indicated by 0 ± 0.5v, and binary 0's by -6v to -12v. Data is not available on either set of 16 lines until both input registers of a pair have been filled.

1.2.4.5 Effects of Malfunction

Since duplicate data is sent to the Data Communications Channel, erroneous data originating from one receiver is rejected by the program.

1.2.5 Model 74 Data Transmitters

1.2.5.1 Function

The Model 74 Data Transmitters (fig. 4-4) accept high-speed digital data from the Output Switch Unit at Goddard and transmit it to the Mercury Control Center via standard telephone lines.

1.2.5.2 Operation and Description

Four single data transmitters are combined into a single integrated data transmitter unit. Each transmitter receives identical serial data as the other three so that the rate of transmission is the same for all four. Each transmitter serially transmits the same data to the Mercury Control Center at the rate of 1000 bits per second. Odd and even data frames (408 bits per frame) are transmitted alternately each second during launch and abort: five times a minute during orbit, and 10 times a minute during re-entry.

1.2.5.3 Inputs

Digital data is serially received by all four transmitters over a common input line from the Output Switch Unit. A message consists of an odd frame and an even frame of 408 bits each. The common input (select-and-ready) line is pulsed by the Data Communications Channel at each end of word. This causes a rise in the line which allows generation of a start-of-message pulse.

1.2.5.4 Outputs

The primary output is a serial readout to a standard telephone line equalized for 1-kc data bit rate. The data is introduced to the line serially as keyed tone bursts with a basic carrier frequency of 2 kc per second modulated with 1/2-ms pulses. Timing requests for the next bit are provided by the data transmitters via a shift line. At each end of word, a 4-1/2-ms keyed pulse of 2-kc carrier is sent over each of the four transmission lines. This is followed by a 2-1/2-ms pulse that indicates the start of the next message.

1.2.5.5 Effects of Malfunction

Malfunction of one of the data transmitters might have the effect of reducing the reliability of the data received by the Mercury Control Center since selection of data from the best three of four transmission lines would not be possible.

1.2.6 IBM 7090 Computers

1.2.6.1 Function

The two IBM 7090 computer units independently accept, and operate upon, radar and telemetry data under program control. One computer is selected by the Output Status Console Operator to provide data to the Mercury Control Center and the remote tracking stations.

1.2.6.2 Operation and Description

The 7090 is a high-speed, general-purpose digital computer having the following characteristics:

a. A large high-speed input-output capability

b. Asynchronous input-output capability

c. A large number of available instructions

d. Two-μsec core memory read-write time

e. Solid state

1.2.6.3 7090 Programming for Mercury

The programs written for Project Mercury have been designed to operate without manual intervention. The various input-output and data-processing routines all operate under the control of the Monitor Control System written for Project Mercury. This control program keeps track of the status of the mission, samples the incoming data, handles priorities and queueing, and temporarily transfers control to the proper routine for operating on the data being received. Figure 4-5 shows the major processing routines and the relationships among them. The diagram does not show the editing routines or timing procedures and does not indicate what types of mathematical computations are used. The operational programs are being documented by personnel from the IBM Space Computing Center, Washington, D. C.

1.2.6.4 Inputs and Outputs

The inputs and outputs of the 7090's are described in considerable detail in Chapter 2.

1.2.6.5 Effects of Malfunction

Each duplexed 7090 receives and operates upon all data so that in the event of malfunction of one computer the other can be switched to provide all output data. This switching is under the control of the Output Status Console Operator, who receives error indications from his console, the plot-boards operators, and the on-line message monitor.

1.2.7 Model 1576B Digital-to-Analog Converter

1.2.7.1 Function

The Model 1576B D/A Converter (fig. 4-4) accepts digital information from the IBM 7090's relevant to computer ouput quality and converts it in to analog voltage information to be used as inputs to two high-speed X-Y plotters.

1.2.7.2 Operation and Description

The D/A unit is composed of four 10-bit converter channels and a 48-bit shift register which accepts serial data from a high-speed output subchannel of the Data Communications Channel.

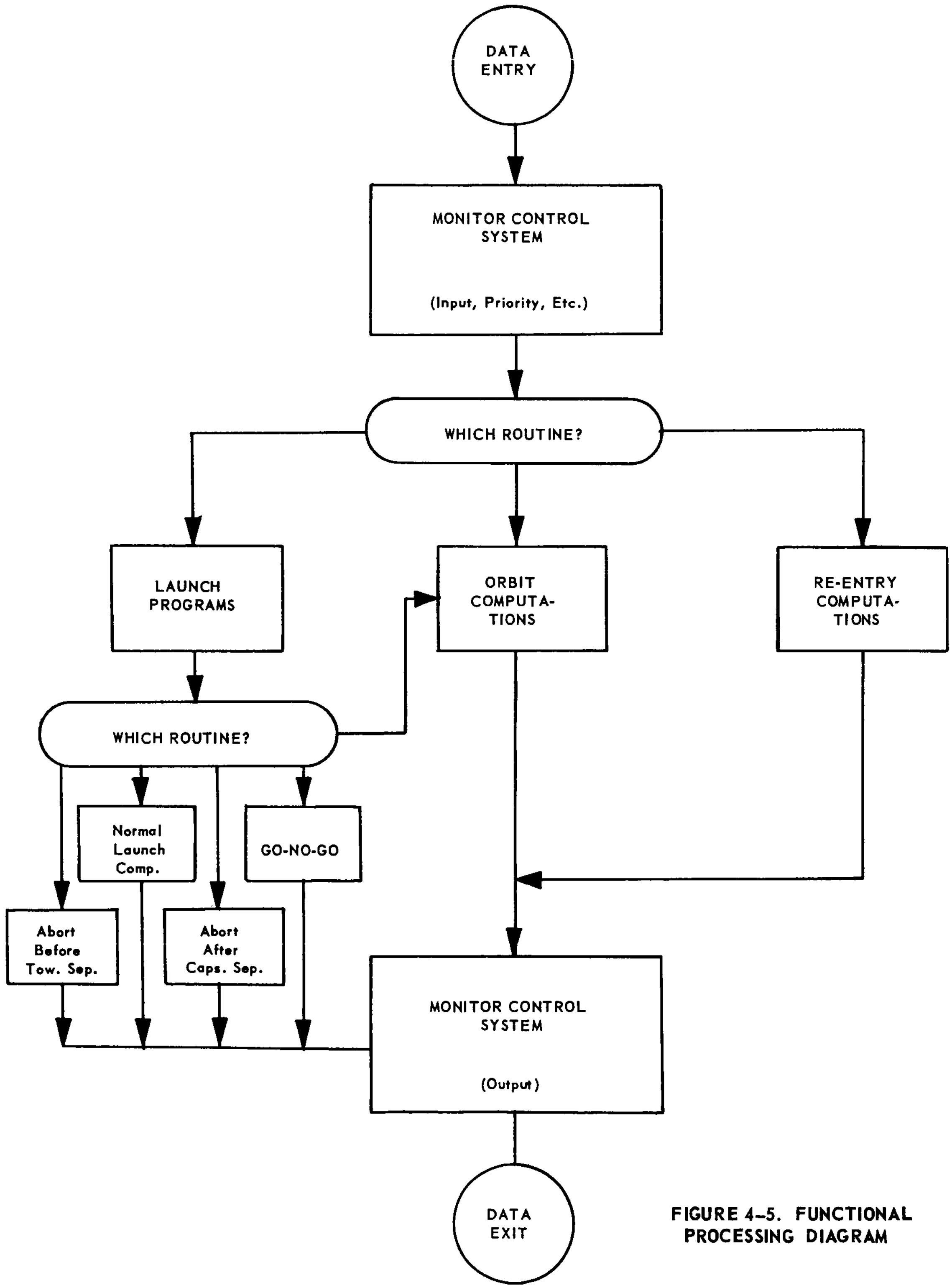


FIGURE 4-5. FUNCTIONAL PROCESSING DIAGRAM

The D/A ready line is pulsed to indicate that the D/A converter is ready to accept data. A drop in the select-and-ready line signals that the digital message is to be converted. The four conversion channels then decode the 40 bits into voltages that activate the plotter pens. Bits 41 through 48 are used to generate control signals to the plot boards.

1.2.7.3 Inputs

Data input is in the form of 48-bit messages received serially. A binary 1 is represented by an input level of 8v ±5v and a binary 0 by a level of 0v ±0.5v. Three lines are associated with input: the select-and-ready, data, and sample lines. The select-and-ready line is up to indicate data is being fed to the D/A unit. When the correct number of bits are received, the select-and-ready line drops. At the same time, the data line has the first bit for sampling. The sample line then causes readin from the data line to the shift register. The data is transfered from the 7090 via the Data Communications Channel to the D/A converter at a rate of 1000 bits per second.

1.2.7.4 Outputs

The primary output is in the form of four separate analog voltages which drive the plotter pens. When the digital input is all 0's, the output is -35v; when all 1's, + 35v.

Four independent control lines are provided to lift each pen. In addition, two control lines are used to place the arms in a standby position.

1.2.7.5 Effects of Malfunction

Complete failure of the D/A converter would eliminate the plot boards as a source of computer output quality information. However, the Output Status Console, the on-line printer, and the Data Selection Supervisor at Cape Canaveral are additional sources of such information.

1.3 EQUIPMENT AT BERMUDA

1.3.1 Model 79 Transfer Register

1.3.1.1 Function

The Model 71 Transfer Register (fig. 4-6.) receives serial digital data from the Data Communications Channel of the IBM 709 computer and arranges these data in proper format for display. A portion of the received data is transmitted in serial format to a D/A converter for display on a plot board; the remainder is stored for parallel readout to displays.

1.3.1.2 Operation and Description

The unit consists of a 56-bit shift register and two 56-bit storage registers, with associated control equipment.

The select-and-ready line from the computer rises to a significant level to indicate that the computer is ready to transmit one complete frame (96 bits) of data. The sample line is then pulsed to cause readin from the computer to the shift register. This line is not pulsed until indication lines from the transfer register (TR ready) and the D/A converter (D/A ready) are raised to indicate that these equipments are ready to accept the next bit of data. Readin of each bit from the data line is caused by a pulsing of the sample line. Each bit is shifted as received. After the first 56 bits are received, each additional incoming bit causes one of the first 40 bits to be shifted out of the 56-bit shift register, serially, to the D/A converter unit which feeds the plot board. After all 96 bits of the frame have been transmitted by the Data Communications Channel, the select-and-ready line drops. This causes the data stored in the shift register to be transferred to a 56-bit storage register for distribution to displays.

Alternate frames of data are stored in alternate storage registers under the control of two bits from the Data Communications Channel. A data frame is received approximately every 500 ms: first, a 96-bit odd frame, then a 96-bit even frame.

This unit also furnishes select-and-ready, sample, and data lines to the D/A converter. These lines operate in a manner similar to the lines between the computer and this unit.

A selector switch enables cycling of bits into the unit in the following formats:

a. All 1's

b. Alternate 1's and 0's

c. Complement of b

d. All 0's

Neon lamps indicate the information stored in the registers.

1.3.1.3 Inputs

Input signals are received, from a high-speed subchannel of the Data Communications Channel associated with the IBM 709 computer, over three lines: select and ready, data, and sample. In each case, a binary 1 or significant level is indicated by $+8 \pm 2$v, and a 0 or nonsignificant level by 0 ± 0.5 v.

In addition, one signal line D/A ready, is accepted from the D/A converter. A level of 0 ±0.5v signifies D/A ready. A level of -6 ±0.5v signifies D/A not ready.

1.3.1.4 Outputs

Output signals are transmitted from this unit to digital displays and to the D/A converter. Control signals are presented to the Data Communications Channel of the IBM 709 computer and the D/A converter.

Output signals to displays are parallel d-c levels. A 1 is represented by -17 ±3v; a 0, by 0 ± 0.5v.

The outputs to the D/A converter consist of a data line and two control lines, select and ready and sample. These lines function in the same manner as those between the Data Communications Channel and the transfer register.

A control line presents a transfer-register-ready signal to the Data Communications Channel. A level of -0.2 ± 0.5v indicates a significant level; a level between -12.48 and -5.56v indicates a nonsignificant signal.

1.3.2 Model 1576 Digital-to-Analog Converter

1.3.2.1 Function

Digital data concerning the flight of the Mercury capsule are processed by the IBM 709 computer at Bermuda. The Model 1576 D/A Converter (fig. 4-6) accepts 40 bits of the computer output via the transfer register in serial d-c format and converts this information into four analog voltages, suitable for display on a high-speed X-Y plot board.

1.3.2.2 Operation and Description

The D/A converter consists of a 40-bit shift register with associated control equipment, four channels capable of converting a 10-bit digital input into a corresponding analog voltage, and associated power supplies.

The select-and-ready line from the transfer register attains a significant level to indicate that data will be presented. A sample line from the transfer register is then pulsed to cause readin of each bit in serial format into the shift register. This line is not pulsed unless the D/A ready line has been raised to a significant level, signalling that the D/A converter is ready to accept data. The sample line is pulsed 96 times to enter the 96 bits in each incoming message into the 40-bit transfer register. The first 56 bits received contain information for digital displays stored in the shift register of the transfer register. These are shifted completely through the register as the last 40 bits, containing information for display on the plot board, are received. After the last bit is received, the select and ready line level drops, and the 40 bits in the shift register are converted into four analog voltages by the four channels of the converter. Storage is provided so that the analog outputs are held while data is inserted into the shift register in the subsequent cycle.

A complete message is received every 500 ms.

1.3.2.3 Inputs

There are three input lines from the transfer register: the select and ready, sample, and data. On each of these lines, a significant signal, or 1, is indicated by a voltage of $\pm 8 \pm 2$v; a nonsignificant signal, or 0, is indicated by 0 ± 0.5v.

1.3.2.4 Outputs

Each of the four channels drives an output line with an analog d-c voltage. The output has a level of -35v for an input of 10 0's, and a level of ± 35v for all 1's. In addition, a signal-ground and ± 35v reference are supplied.

The converter also supplies a D/A-ready signal to the transfer register. An output of 0 ± 0.5v indicates that the D/A converter is ready to receive data. A level of -6 ± 0.5v signifies that the unit is not ready to receive data.

1.3.3 Radar Data Facilities

1.3.3.1 Function

The primary function of this subsystem is to provide capsule range, azimuth, and elevation (RAE) information to both the Bermuda and Goddard computers.

1.3.3.2 Operation and Description

Radar data are acquired by two precision radars at Bermuda, a C-band AN/FPS-16 and an S-band Verlort. Contained in each of these equipments is an analog-to-digital converter which produces the RAE output information in parallel binary form from the Verlort and in serial binary form from the FPS-16. Output data from each is sent to both the Goddard and the Bermuda computers.

Radar data transmission to Goddard is in serial form, by TTY, at the rate of 10 frames per minute. Data from each radar is transferred to Milgo 165 Digital-to-TTY Converters, which convert the radar output to the appropriate TTY format for transmission to Goddard. Address and end-of-message indications are also generated by these units. The output source that will be used to transmit data in real time to Goddard is selected by the Radar Control Unit under control of the Ground Communications Co-ordinator. Data from the source not selected (ordinarily Verlort) is stored in a 28 ROTR and transmitted to Goddard immediately after each pass.

Output data to be processed by the IBM 709 is transferred from each radar to Milgo 4008T Data Transmitters. At this point, parallel Verlort data is converted to serial. The two 4008T's then transmit serial data over high-speed lines, at the rate of 10 frames per second, to two 4008R Data Receivers. The two receivers operate together to produce a synchronized, simultaneous, 8-bit parallel input to a single, high-speed input subchannel of the Data Communications Channel. The data then enters the 709 under program control.

1.3.3.3 Effects of Malfunctions

Depending upon the location, a malfunction within this part of the system could result in a failure to transmit FPS-16 data, Verlort data, or both to the Bermuda 709 and/or the Goddard 7090's.

1.3.4 Data Communications Channel

1.3.4.1 Operation and Description

The physical design of the Bermuda Data Communications Channel (fig. 4-6) is identical with that of the Data Communications Channel at Goddard (par. 1.2.1). However, since the Data Communications Channel is a transistorized unit, an adapter unit is required to connect it to the IBM 709, which is a tube device.

The Bermuda Data Communications Channel differs from the Goddard unit chiefly in its input-output configuration. One high-speed input subchannel receives simultaneous data from the AN/FPS-16 and Verlort radars by way of Milgo transmitting and receiving equipment. Upon activation, a telemetry input subchannel transfers data from a telemetry buffer to core in 8-bit parallel words at the rate of one word per sequencer scan. As at Goddard, there are one paper tape input subchannel and three subchannels for timing co-ordination.

Three subchannels have been allocated to handle output data. The sense output subchannel furnishes computer status data to the Output Status Console. The TTY output subchannel feeds data to a TTY distributor. The high-speed output subchannel furnishes data to a transfer register, which in turn feeds data serially to a D/A converter and stores the remainder for parallel readout to displays.

1.3.4.2 Effects of Malfunction

Since the 709 is not duplexed, the effects of a malfunction of the Data Communications Channel depend on both the operational status of the Bermuda site at the time of failure and the nature of the failure. Should failure of the Data Communications Channel occur during the launch phase, Bermuda's capability as an alternate control center would be limited.

1.3.5 Output Status Console

1.3.5.1 Operation and Description

The Output Status Console (fig. 4-6) at Bermuda is similar in design to the Goddard unit (par. 1.2.2). However, since the IBM 709 at Bermuda is not duplexed, its Output Status Console is a less complex device. Only one row of eight lamps is provided, and there are no computer output and computer to D/A switches. Computer inputs to the unit are of the same form as at Goddard.

1.3.5.2 Effects of Malfunction

Malfunction of the unit would result in failure of the operator to detect indications of faulty computer output. However, the on-line printer also provides this type of information.

1.3.6 Bermuda IBM 709 Computer

1.3.6.1 Function

The Bermuda 709 computer is active in providing display quantities whenever the capsule is in range of the Bermuda tracking system.

1.3.6.2 Operation and Description

The 709 is a high-speed, general-purpose digital computer. Detailed description of the computer and its operation are available in IBM reference manuals.

The operational programs for this computer are under the control of the Monitor Control programs written specifically for Bermuda's role in the Mercury mission. By sampling the information provided by the telemetry system, the monitor program keeps track of the status of the mission, controls the input and output of the 709, and through its knowledge of mission progress temporarily transfers control to the proper subroutine for the necessary computations.

In brief, the computer always edits and smooths the radar returns it receives at the rate of 10 per second. Prior to SECO +10 seconds, the computer essentially uses a least-squares method for curve fitting to derive parameters for output to the local displays. After this time, a short arc orbit determination is utilized until the capsule is out of range. The output quantities provided by the 709 computer are discussed in paragraph 3.4.

The programs have been written so that the 709 will operate automatically without intervention from the operator. The programs have been written to accept a paper tape input which is manually inserted (par. 1.3.7).

1.3.7 Computer-Related Teletypewriter Communications (Bermuda)

1.3.7.1 Function

This portion of the teletypewriter communications subsystem provides a means of transmitting TTY data to and from the IBM 709.

1.3.7.2 Operation and Description

Two subchannels of the Bermuda Data Communications Channel are provided for reception and transmission of TTY data. One of these subchannels accepts manually inserted TTY data, and the other handles that portion of the IBM 709 output to be sent to Goddard via TTY equipment.

Normally, the only TTY data used as an input to the IBM 709 is GMT of liftoff. However, in the event that the Bermuda T/M receivers are not in operation, the GMT of retrofire, the number of retrorockets fired, and retro-attitude (all transmitted by Goddard) will also be used. This data is contained on punched tape in 5-bit serial form and accepted by a 28ASR. The unit generates and transmits input signals to a 28 ROTR, which converts the data into parallel form and transfers it to the Data Communications Channel.

The IBM 709 output for transmission to Goddard by TTY consists of capsule position and velocity data during launch and insertion and smoothed AN/FPS-16 and Verlort data during subsequent passes. The TTY output subchannel of the Data Communications Channel transfers parallel data to a 28A distributor, which converts it into serial form. The 28A then distributes data to one 28RO, one 28ROTR, and control circuitry. The 28RO prints locally derived acquisition data; the 28ROTR provides a record copy of output data on punched, typed tape; and data is selected for transmission to Goddard by the control circuitry.

SECTION 2

TRAFFIC DELAYS

The Launch Monitor Subsystem has been designed to receive, process, and distribute operational data with as little delay as possible. The design of this high-speed system was dictated by the operational requirements present during the launch phase of the mission. It is during this phase that flight controlling personnel are responsible for making several decisions that must be both timely and accurate. With the exception of voice communications and telemetry, all operational information arrives at the Mercury Control Center over some portion of the Launch Monitor Subsystem communications and data flow network.

In examining the delays of operational traffic through the Launch Monitor Subsystem, there are two paths of primary interest. Within the Launch Monitor Subsystem, these paths originate at the high-speed buffers and retransmitters associated with the IP 709 and Burroughs-GE Complexes. To give meaningful figures on traffic delay, it is necessary to go beyond the limits of the Launch Monitor Subsystem and begin at the prime source of information. For both of these high-speed data paths, the prime source is the radars which track the launch vehicle and capsule.

As used in this context, traffic delay is an all-inclusive term that refers to the total time differential between instantaneous radar readings and the ultimate display of quantities based on these readings. There are a number of factors, however, contributing to the total delay of operational traffic. Tables 4-6 and 4-7 are a summary of all significant delays incurred in the treatment of smoothed radar data.

As shown in tables 4-6 and 4-7 the nominal delays from Burroughs-GE and IP 709 are 2.000 and 2.400 seconds respectively. In the event that the system is obliged to operate with raw radar data, the pertinent transmission and buffering delays will be the same as IP 709 timing, but the total deviation from real time will be affected most by the extent and type of smoothing performed by the Goddard computers. Exact figures on this are not available at this time.

The Bermuda Complex has also been designed to approach real-time presentation of data to its local displays. Deviations from real time are incurred, but their value depends on the status of the mission. Up to SECO +10 seconds, the displays are approximately 3.5 seconds behind real time. When powered flight has ended, the displays very closely approach real time, the deviation being on the order of 1.0 second, which is the rate at which the plots are updated. This close approach to real-time display is possible, after powered flight, by projecting display points, based on the short arc orbit determination routine, which will operate on either AN/FPS-16 or Verlort radar data.

TABLE 4–6. BURROUGHS-GE DATA TIMING

Operation	Seconds		
	Minus	Nominal	Plus
Actual occurrence	0.000	0.000	0.300
Computer outputs to computer buffer	0.050	0.650	0.050
High-speed buffer transmission	0.000	0.400	0.000
Transmission to Goddard	0.002	0.013	0.002
Delay between paths 1 and 2: 0.001 second through 0.016 second by integral values (steps)	0.002	0.002	0.014
Transfer into 7090	0.000	0.005	0.000
7090 computational cycle	0.000	0.500	0.000
Transfer from 7090 to buffer register in 8-bit byte and into receiving register	0.000	0.408	0.000
Transmission to Mercury Control Center	0.002	0.013	0.002
Delay between return paths 1, 2, 3, and 4	0.006	0.006	0.014
Transfer to flip-flop register	0.000	0.000	0.000
Transfer to plot boards	0.000	0.003	0.000
Alternate data	0.000	0.000	0.500
Difference from nominal	0.062	0.000	0.882
Total time	1.938 Min	2.000 Nom	2.882 Max

TABLE 4-7. IP 704 DATA TIMING

Operation	Seconds		
	Minus	Nominal	Plus
Radar sensing	0.000	0.000	0.100
A/D conversion and transmission to Milgo 1002R	0.000	0.150	0.000
Smoothing process	0.000	0.500	0.000
Computation cycle and transmission to buffer	0.000	0.400	0.000
Total buffering time	0.000	0.400	0.000
Transmission to Goddard	0.002	0.013	0.002
Delay between paths 1 and 2: 0.001 second through 0.016 second by integral values (steps)	0.002	0.002	0.014
Transfer into 7090	0.000	0.005	0.000
7090 computational cycle	0.000	0.500	0.000
Transfer from 7090 to buffer register in 8-bit byte and into receiving register	0.000	0.408	0.000
Transmission to Mercury Control Center	0.002	0.013	0.002
Delay between return paths 1, 2, 3, and 4	0.006	0.006	0.014
Transfer to plot boards	0.000	0.003	0.000
Difference from nominal	.012	0.000	.162
Total time	2.388 Min	2.400 Nom	2.562 Max

SECTION 3

OPERATOR PROCEDURES FOR CONTROL OF SUBSYSTEM

Although the Launch Monitor Subsystem is largely automatic, some operator control functions are required. The following functions require operator intervention:

a. Selection of the data sources from which the subsystem will provide displays to the Mercury Control Center

b. Switching between duplexed equipment and transmission facilities upon detection of a malfunction

c. Selection and insertion into the computers of events and quantities received at Goddard

d. Determination of the occurrence of selected critical events and, if necessary, overriding of the telemetry indications of these events.

The duties and procedures of each operator concerned with these functions are detailed in the paragraphs that follow.

3.1 DATA SELECTION SUPERVISOR

3.1.1 Functions

The Data Selection Supervisor is responsible for selecting the source of computed data that will activate various displays at the Mercury Control Center. This selection is based on his evaluation of data quality information associated with each of the data sources together with data source requirements related to mission phase.

To evaluate data quality during launch, the Data Selection Supervisor monitors information displayed on both a strip chart recorder (Data Quality Monitor) and a console (Data Quality Monitor Console). On six channels of the recorder are plotted values of $V/V_R - V/V_R$ (nom) and $\gamma - \gamma$ (nom) for each of three data sources. These sources are Burroughs-GE direct, Burrough-GE processed by 7090, and IP 709 or raw radar processed by 7090. A set of four lamps on the console provides an additional indication of the quality of direct Burroughs-GE data.

The Data Selection Supervisor operates three 2-position switches on the console to control the selection of data source. One of these switches determines whether the 7090's at Goddard process Burroughs-GE or IP-709 data; another selects Burroughs-GE or 7090 data to activate Plot Boards I and II, and the go, no-go recommendation; a third selects either 7090 or Burroughs-GE data to drive Plot Board III. Two other switches also appear on the console. One of these is a 3-position switch that informs the 7090's of mission phase (launch, abort, or orbit), and the other determines which of the two receiving registers will receive 7090 data.

Included in the responsibilities of the Data Selection Supervisor are a local unit test and participation in the Launch Monitor Subsystem check. Following these checkouts, he assures that the three data source switches are positioned to select Burroughs-GE data and that the flight phase switch is in the LAUNCH position. He then monitors the strip charts and the Burroughs-GE lamps. If direct Burroughs-GE data is poor, he selects 7090 processed data to drive Plot Boards I and II, and the go, no-go recommendation. However, the switch controlling data flow to Plot Board III must remain in the Burroughs-GE position throughout launch.

In the event of an abort, the Data Selection Supervisor sets the flight phase switch in the ABORT position. He then selects IP 709 data to be processed by the 7090's and 7090 data to drive Plot Boards I and II. Plot Board III is not used during an abort.

At the Flight Dynamics Officer's signal, the Data Selecting Supervisor instructs the 7090's to transmit orbital data by the appropriate setting of the flight phase switch. He then positions the data switches so that the 7090's will process IP 709 data and Plot Boards I, II, and III will be furnished with 7090 data.

Throughout the mission, the Data Selection Supervisor receives information relative to the status of the receiving registers from the Assistant Data Selection Supervisor. He selects the register indicated by these reports. A functional equipment description is given in paragraphs 1.1.6 and 1.1.7.

3.1.2 Procedures

A local unit check is required of the Data Selection Supervisor as well as his participation in the computer-programmed Launch Monitor Subsystem check. Following the above checks, the Data Selection Supervisor sets the console switches at positions appropriate to the launch phase of the mission:

A. Prelaunch

1. Set 3-position flight phase switch to LAUNCH (center) position.

2. Set to B-GE position the 2-position switch that determines whether 7090's will process B-GE or IP-709 data. Two lamps will indicate and confirm selection.

3. Set to B-GE position the 2-position switch that selects B-GE or 7090 data to drive Plot Boards I and II and the GO-NO-GO recommendation. Two lamps will indicate and confirm selection.

4. Set to B-GE position the 2-position switch that selects B-GE or 7090 data to drive Plot Board III. Two lamps will indicate and confirm selection.

5. Set 2-position receiving register switch in either position. Two lamps will indicate and confirm selection.

B. Launch

The Data Selection Supervisor hears the liftoff announcement. He monitors the strip chart recorder and the B-GE lamps on the console:

1. Evaluate quality of B-GE direct data from information observed on both displays:

   (a) If data quality good, leave switches as positioned for launch phase.

   (b) If data quality deemed poor:

      (1) Set Plot Board I and II switch in 7090 position. Selection indicated and confirmed by lamps.

      (2) Leave Plot Board III switch in B-GE position.

2. Evaluate sources of data processed by 7090 from values observed on strip recorder:

   (a) If B-GE data as processed by 7090 is considered good, leave 7090 switch in B-GE position.

   (b) If B-GE data as processed by 7090 is not acceptable, set 7090 switch in IP-709 position. Selection is indicated and confirmed by lamps.

   (c) If neither of above sources is reliable, raw radar data normally processed by IP 709 will be directly processed by 7090:

(1) Set 7090 switch in IP-709 position.

(2) Order operator at 709 to switch to raw radar.

(3) Lamp confirms that 7090 is processing raw radar data.

The Data Selection Supervisor keeps the Flight Dynamics Officer informed of data quality, receives reports from the Assistant Data Selection Supervisor concerning the status of the Data Receivers and Comparator and Receiving Register Units. He changes the position of the register switch if necessary.

C. Abort

The Data Selection Supervisor receives message indicating abort from the Flight Dynamics Officer and sets the console switches at positions apropriate to abort:

1. Set 3-position flight phase switch to ABORT (left) position (only when abort occurs after SECO). Selection indicated by lamp.

2. Set 7090 switch to IP-709 position. Selection indicated and confirmed by lamps.

3. Set Plot Board I and II switch to 7090 position. Selection indicated and confirmed by lamps.

4. Plot Board III not used during abort.

D. Orbit

The Data Selection Supervisor receives the orbit message from the Flight Dynamics Officer and sets the console switches in positions appropriate to the orbit phase.

1. Set 3-position flight phase switch to ORBIT (right) position. Selection indicated by lamp.

2. Set 7090 switch to IP-709 position. Selection indicated and confirmed by lamps.

3. Set Plot Boards I and II switch to 7090 position. Selection indicated and confirmed by lamps.

4. Set Plot Board III switch to 7090 position. Selection indicated and confirmed by lamp.

The Data Selection Supervisor receives reports from the Assistant Data Selection Supervisor concerning Data Receivers and Comparator and Receiving Register Units. He changes the position of the register switch if necessary.

3.2 ASSISTANT DATA SELECTION SUPERVISOR

The principal functions of the Assistant Data Selection Supervisor are to select three of the four data receivers to feed binary data to the two (duplexed) comparator and receiving register units and to recommend to the Data Selection Supervisor which of the latter units should furnish data for the Mercury Control Center displays.

To aid in the selection of the three data receivers, an indication of erroneous bits associated with each receiver is displayed on a meter and an alarm lamp is lighted whenever the error rate of any one receiver is in excess of a predetermined level. A 4-position switch is provided for the selection of the receivers that will be used as inputs for the comparators.

Two displays indicate comparator and receiving register functioning. One of these is a set of neon lamps that gives a visual indication of the information stored in the receiving registers. The other is a red lamp alarm which lights whenever the internal voltage supply of the unit fails. (See fig. 4-7.)

The Assistant Data Selection Supervisor is required to make a local unit test prior to launch. In addition, he participates in conjunction with the Data Selection Supervisor in the programmed Launch Monitor Subsystem check. Upon completion of these checks, he observes the data receiver error meters. He then sets the 4-position switch so that the receiver with the highest error rate will not feed data to the comparator and reports this action to the Data Selection Supervisor. The prelaunch test determines which comparator and receiving register unit will be put in operation. Should inspection of the 579 neon lamp display or voltage alarm lamp indicate malfunction of this unit, the Assistant Data Selection Supervisor advises the Data Selection Supervisor to change the position of the register switch on his console. He then releases the malfunctioning unit for maintenance.

3.3 CAPSULE COMMUNICATOR, CAPE CANAVERAL

Part of the Capsule Communicator's task is to verify telemetry event data that is to be transmitted to the Telemetry Event Transmitting Buffer. His console (fig. 4-8) is equipped with a set of lamps which, when lighted, indicate the occurrence of certain discrete telemetry events. Twelve of these lamps each have an associated 3-position switch which may be positioned by the Capsule Communicator to correct the telemetry data as indicated by the lamps.

To aid him in this function, the Capsule Communicator interrogates the astronaut by direct radio concerning event occurrence and also monitors the

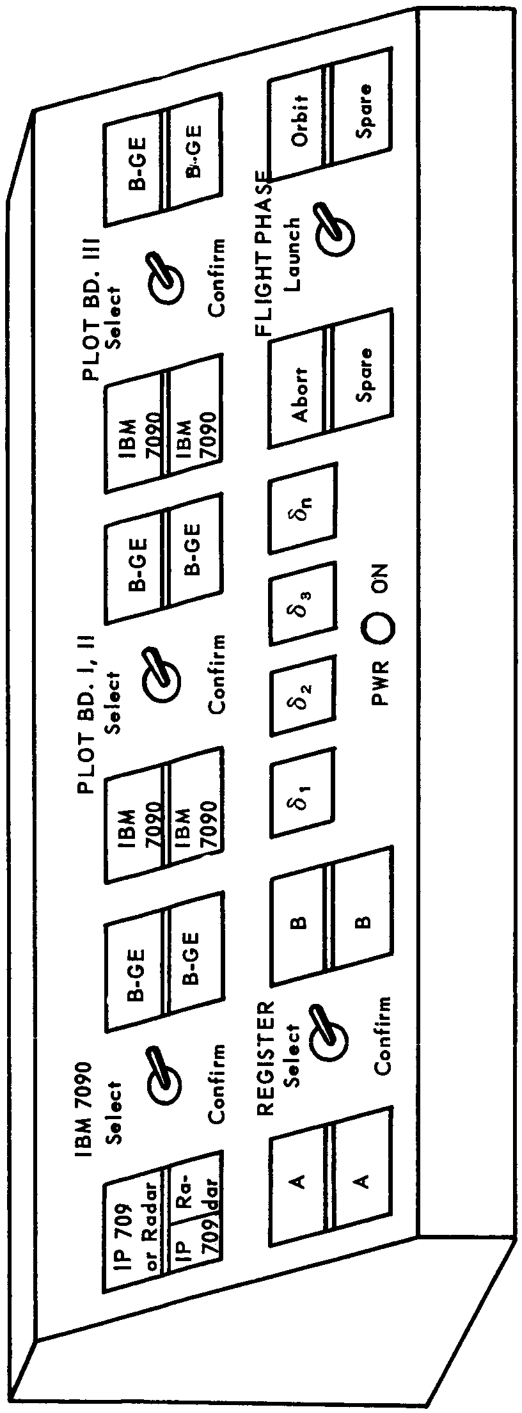


FIGURE 4-7. DATA QUALITY MONITOR CONSOLE

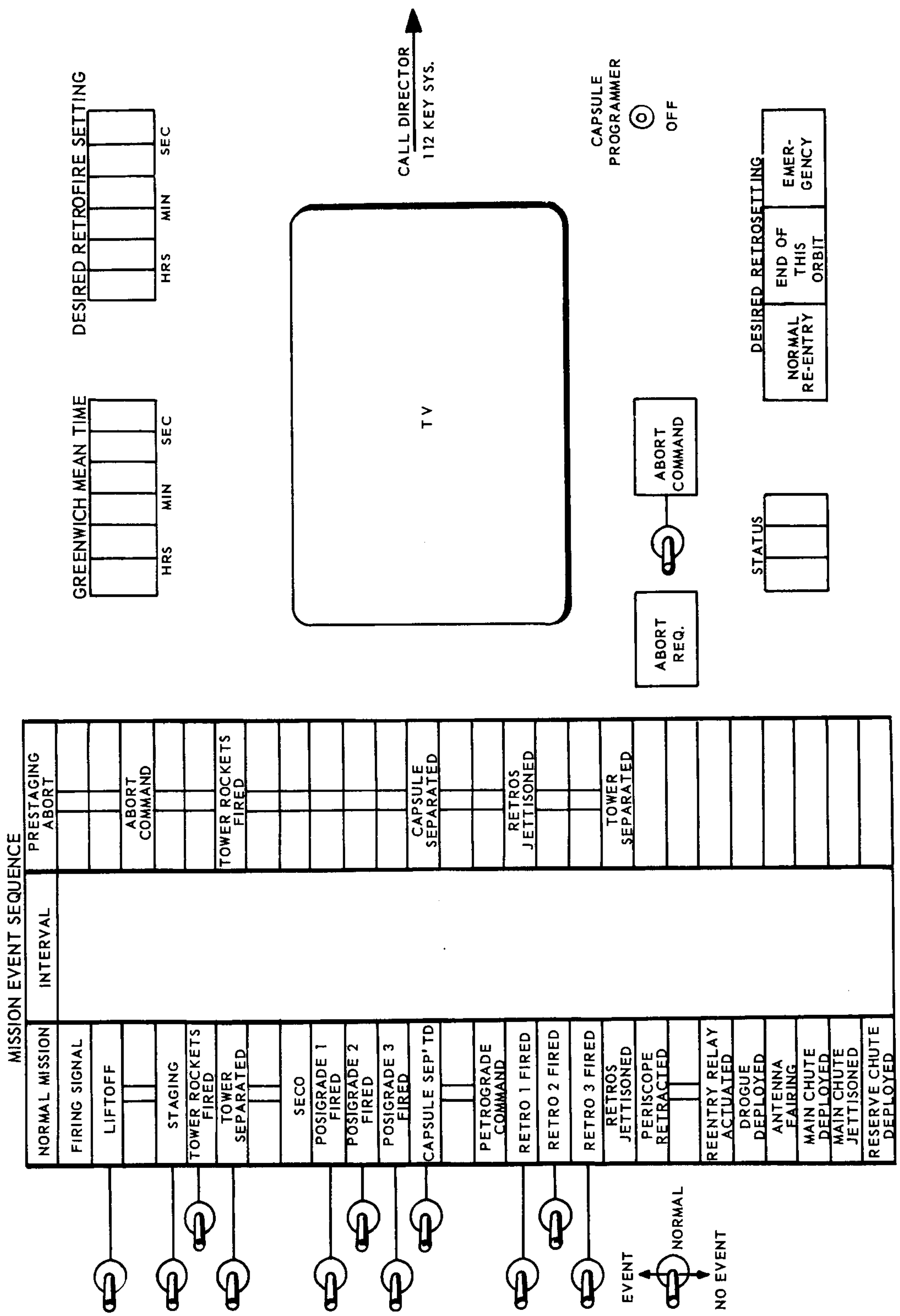


FIGURE 4-8. CAPSULE COMMUNICATOR'S CONSOLE

TV screen at his console. Should these sources of information indicate an event did or did not occur and the console event displays are not in agreement, the Capsule Communicator sets the override switch in the appropriate position. If the telemetry data is not in error, the switch remains in its normal position. (See par. 1.1.11.)

3.4 IP 709 BUFFER SWITCH OPERATOR

An operator is stationed at the IP 709 Input Buffer and Dual Data Retransmitter described in paragraph 1.1.2. This unit is equipped with a 2-position switch selecting radar data processed by the IP 709 or raw radar data.

During the launch phase, this switch remains in the PROCESSED position until the 709 computer operator, (in the event of computer failure), the Data Selection Supervisor, or the Flight Dynamics Officer orders a change to the RAW RADAR position. The use of raw radar data may be required prior to SECO because of the failure of the 709 computer. After SECO, a switch to raw radar is commanded so that the 709 with Azusa input can provide data on the launch vehicle sustainer. This command comes from the Flight Dynamics Officer.

When the orbit phase is achieved and the Cape Canaveral radar is no longer receiving valid data, the Flight Dynamics Officer orders the switch returned to the PROCESSED position. This is necessary to permit assembly within the buffer of telemetry messages in the 72-bit format required by the orbit program at Goddard.

The IP 709 Input Buffer is also equipped with a 5-position radar selector switch which allows selection for input among the FPS-16 radars at Cape Canaveral, Grand Bahama, and San Salvatore. (Other positions are spare and remote.) This selection is made by the operator whenever the first switch is in the RADAR position.

3.5 OUTPUT STATUS CONSOLE OPERATOR, GODDARD

The chief function of the Output Status Console Operator is to select one of the two IBM 7090 computers to furnish data to the Mercury Control Center and the TTY transmitters. His selection depends on an evaluation of data quality information appearing on his console, the two X-Y plotters, and the on-line messages.

Computer output quality is presented on the console by means of one row of eight indicator lamps for each computer. (See fig. 4-9.) One of the lamps is also accompanied by an audible alarm. The types of error indicated by the lamps will be defined at the time the system becomes operational.

The Output Status Console Operator also receives computer output information from the plotter and on-line message monitors. Plot Board information

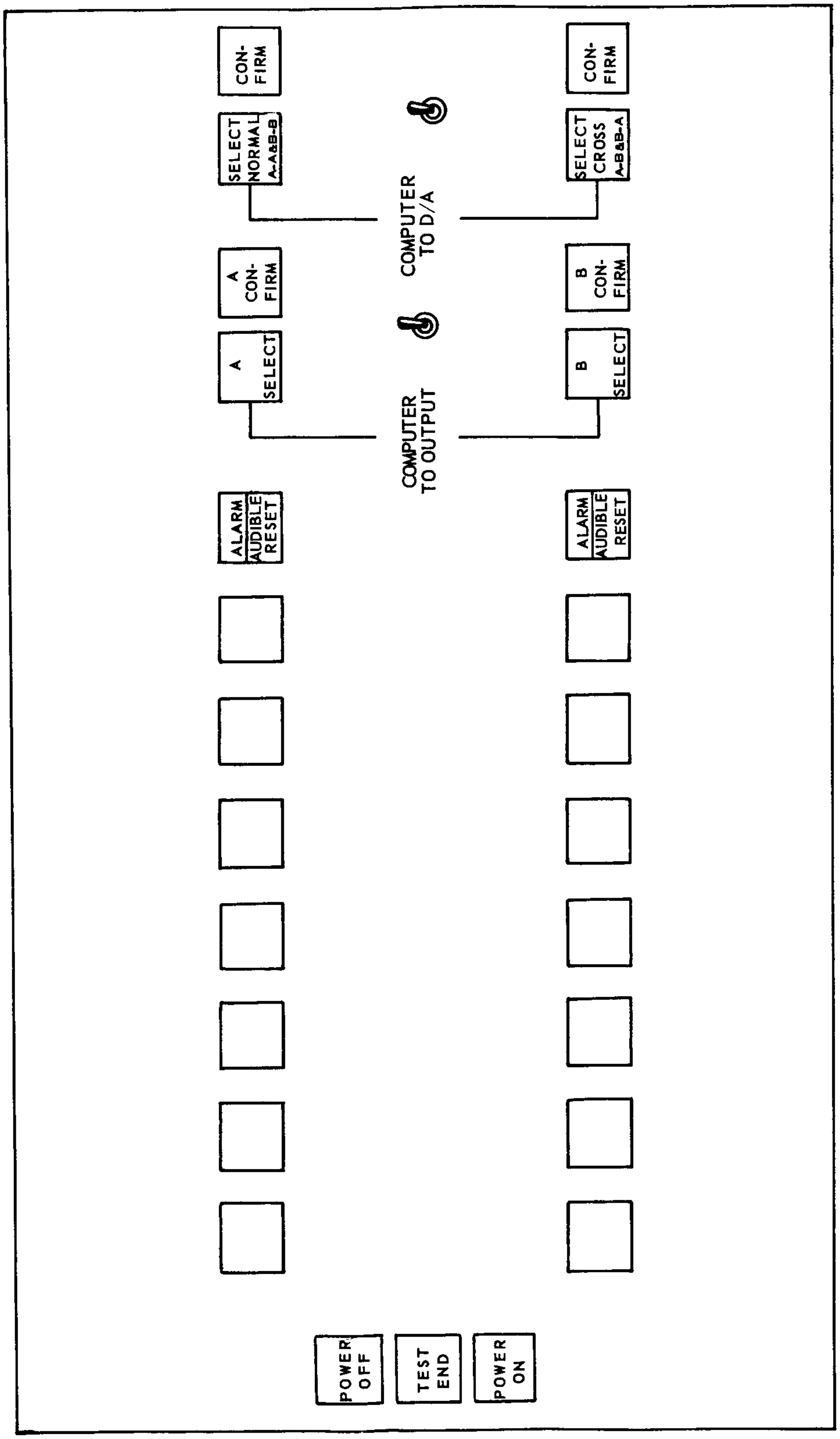


FIGURE 4-9. OUTPUT STATUS CONSOLE – GODDARD

is composed basically of residual to standard error ratios for R, A, E, for each range station and relative to time.

There are two 2-position switches located on the console: one selects which 7090 will provide output data; the other controls computer output to the D/A converters. In one position, Computers A and B activate D/A converters A and B respectively. Conversely, in the second position, Computers A and B activate D/A converters B and A, respectively. Two lamps for each switch position indicate and confirm the selection.

The Output Status Console Operator is responsible for a local unit check prior to launch and also participates in the computer-programmed Launch Monitor Subsystem check. Following these checks, he monitors his console displays for error indications and evaluates data quality reports from the plotter and online message monitors. Should he judge the output of the computer in use to be unacceptable, he changes the position of the computer to output switch. In the event that the two X - Y plotters do not agree, the disagreement can be attributed to the proper source (computer output or plotter) by operating the computer to D/A switch.

The Output Status Console Operator is able to communicate with the Data Selection Supervisor at Cape Canaveral via an open-loop intercom. The Data Selection Supervisor will then be another source of output quality information.

3.6 MANUAL DATA INSERTION, GODDARD

Certain discrete quantities received at Goddard via teletype from Mercury sites are not required on a real-time basis. Provision has been made, therefore, for the manual insertion of these data. The procedures for insertions of the data and the data themselves differ for pre- and post-launch periods.

The prelaunch data for manual insertion is received by teletype on Meteorological and Boresight Data messages from all radar sites approximately one hour before launch. The messages consist of five items: atmospheric temperature, total pressure, water vapor pressure, azimuth of boresight tower, and elevation angle of boresight tower. They are edited and keypunched on cards. They are then inserted in the card reader and used as an input to update a station characteristic tape.

After launch, the paper tape inputs are used for manual insertion rather than the card readers. An operator is assigned to each of the two paper tape readers. The operators monitor the incoming teletype messages and extract the following quantities:

a. GMT of lift off from Cape Canaveral as soon as possible after occurrence.

b. Capsule position and velocity and the associated GMT from Bermuda following insertion.

c. ECT, ECTRS, GMT, and station identification from all sites. These quantities appear in the station's summaries.

d. GMT of each retrofire and number of retrorockets fired.

e. Retro-attitude.

The operators are then responsible for punching these quantities on paper tape as soon as possible after reception and insert the tape in the paper tape reader.

3.7 PLOT BOARD MONITORS, GODDARD

There are two X - Y plotters at Goddard, each driven by a D/A converter. Information plotted consists of the ratio of residuals to the standard error for R, A, E for each range station. These plots are relative to time. A monitor stationed at each plot board observes the plotted values to form a judgment of computer output quality. Each monitor reports his observations to the Output Status Console Operator, who uses this information in his evaluations of computer functioning.

3.8 OUTPUT STATUS CONSOLE OPERATOR, BERMUDA

The Output Status Console at Bermuda is similar to the one at Goddard. (See par. 3.5.) The primary difference is that only one row of eight indicator lamps is provided. The Output Status Console Operator is responsible for evaluating the computer output; but, since the 709 is not duplexed, he has no switching function. Should he judge the output to be unacceptable, he reports his evaluation to the Flight Dynamics Officer. The report is also sent in a high-priority message to the Mercury Control Center via Goddard.

3.9 CAPSULE COMMUNICATOR, BERMUDA

As at Cape Canaveral, the Bermuda Capsule Communicator has the function of verifying certain discrete telemetry events. (See pars. 1.1.13 and 3.9.) However, this responsibility begins with firing of the first posigrade rather than liftoff. In addition, the telemetry data is processed by the 709 rather than the 7090's.

CHAPTER 5

CHRONOLOGICAL SEQUENCE OF EVENTS

To be issued at a later date.

APPENDIX A

TERMS AND SYMBOLS

Appendix A defines the Terms and Symbols used in this manual

APPENDIX A

TERMS AND SYMBOLS

Terms

a	The semimajor axis of the orbital ellipse.
a, as a subscript	Apogee; the farthest point of the orbit from the earth.
a_T	Acceleration, from telemetry.
A	Abort phase: From rejection of trajectory to escape rocket fire or retrorocket fire.
b	The semiminor axis of the orbital elipse.
BECO	Booster engine cutoff.
CET	Capsule elapsed time.
d	Distance, in a horizontal direction, from the launch pad.
D/A	Digital to analog converter.
E	Elevation angle; in a range, azimuth, elevation system.
ECTRC	Elapsed capsule time for retrofire, computer recommendation.
ECTRS	Elapsed capsule time of retrofire, setting in capsule clock.
EGT	Elapsed ground time.
GMT	Greenwich mean time.
GMTLC	Greenwich mean time of landing computed.
GMTRC	Greenwich mean time for retrofire, computed, computer recommendation.
GMTRS	Greenwich mean time of retrofire based on present capsule setting.
GO, NO-GO	The recommendation, by a computer, as to whether the flight should be continued.

GTRS	Ground time remaining until retrofire setting is reached.
h	Altitude above oblate (flattened at the poles) earth.
i	The inclination angle, which is the angle between the equatorial plane and the orbital plane.
ICTRC	Incremental capsule time for retrofire, or amount setting would need to be changed, computer recommendation.
ins, as a subscript	The nominal value, at any time.
O	Orbit phase: from acceptance of trajectory to retrorocket fire.
r	Geocentric radius: The distance of the capsule from the center of the earth.
$r-\bar{R}$	Height above spherical earth.
R	Range; in a range, azimuth, elevation system.
R	Re-entry phase: From escape rocket fire or retrorocket fire to recovery.
$\bar{R}$	Reference radius of earth, which is 20, 910,000 feet.
SECO	Sustainer engine cutoff.
Staging	Atlas booster dropoff
t, or Te	Time that has elapsed since liftoff.
TN	Time remaining until sustainer engine cutoff.
ΔT	The nominal time, at any instant, before the retrorockets can be fired to achieve impact in the next designated recovery area.
V	Velocity.
VR	Velocity required to achieve the planned orbit.
V_y	Velocity in a direction perpendicular (left or right) to the planned direction.
x, y, z	Rectilinear co-ordinates with origin at the launch pad as follows:

z	Vertical height, in nautical miles, in a direction normal to the Clarke 1866 spheroid.
x	Distance, in nautical miles, in the direction of the planned launch azimuth, and perpendicular to z.
y	Distance, in nautical miles, in a direction perpendicular to x and z. Positive values are North (to the left) of the planned launch azimuth.
$\dot{x}$, $\dot{y}$, $\dot{z}$	Velocity in the directions described for x, y, and z.
Y-Ynom	The deviation of the actual value Y from a nominal value of Y for this particular trajectory.
Xp, Yp, Zp	IP 709 co-ordinate system, a right-hand system giving vector position in geocentric inertial space, redefined at each computing cycle. The Z axis is the earth's rotational axis (positive north), and the X, Y plane is the equatorial plane. The X axis (positive value) passes through the Greenwich meridian.
X, Y, Z	Mercury inertial co-ordinate system. In this system, the Z axis is the axis of rotation of the earth, with positive values northward, the X axis (positive value) is directed from the center of the earth toward the vernal equinox, and the Y axis lies in the earth's equatorial plane and forms a right-handed set. The origin is at the center of the earth.

Symbols

Γ (Gamma)	Flight path angle. Angle between a plane tangent to an expanded earth sphere passing through the capsule, and the direction of flight.
δ (Delta)	B-GE computer flags, as follows:

$$\delta_1 \begin{cases} 1 = \text{Good data} \\ 0 = \text{Computer is integrating rates of change to obtain R, A, E} \end{cases}$$

$$\delta_2 \begin{cases} 1 = \text{Good data} \\ 0 = \text{Computer is differentiating R, A, E to obtain rates of change} \end{cases}$$

$$\delta_3 \begin{cases} 1 = \text{Good data} \\ 0 = \text{Computer is differentiating only for lateral rates} \end{cases}$$

$\delta\eta \begin{cases} 1 = \text{Good data} \\ 0 = \text{Computer is not computing guidance commands; not enough information} \end{cases}$

ϵ (Epsilon) The eccentricity of the orbit.

$$= \frac{a^2 - b^2}{a}$$

ξ (Xi), η (Eta), ζ (Zeta) Co-ordinate system used by Burroughs-GE computer.

It is a right-hand system. The ζ axis lies along the earth's polar axis (positive northward), the ξ and η axes lie in the equatorial plane, and the $\xi\zeta$ plane contains the inertial point occupied by the phase center of the central rate antenna of the GE Mod III radar at the time when the rate data used in any computing cycle were valid. The $\xi\eta\zeta$ co-ordinate frame does not rotate with the earth, although it is redefined each computing cycle.

λ (Lambda) Longitude, plus is East and minus is West.

λ 30 sec The longitude at which the capsule will land if retrofire occurs 30 seconds from now.

λ PP The present longitude of the capsule (present position).

λ Maxdelay The longitude at which the capsule will land if retrofire fire occurs with maximum delay.

λ P The earth-fixed longitude of the perigee (closest, point to earth of the orbit).

ϕ (Phi) Latitude, plus is North and minus is South.

ϕ 30 sec The latitude at which the capsule will land if retrofire occurs 30 seconds from now.

ϕ PP The present latitude of the capsule (present position).

ϕ Max delay The latitude at which the capsule will land if retrofire occurs with maximum delay.